AN ABSTRACT OF THE THESIS OF

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Abstract approved:

Robert G. Anthony

Several large wildfires in southwestern Oregon during the summers of 2001 and 2002 provided the opportunity to investigate the impacts of wildfire on northern spotted owls (*Strix occidentalis caurina*). I used radio-telemetry and demographic surveys to describe demographic performance and habitat selection of spotted owls in the areas burned by the Biscuit, Quartz and Timbered Rock Fires. Demographic surveys were conducted from 2003 – 2006 at the 3 fires. From September, 2004 – August, 2006, 26 spotted owls were monitored with radio-telemetry at the Quartz and Timbered Rock Fires and their surrounding areas.

I investigated differences in occupancy rates between the South Cascades Demography Area and the Timbered Rock Study Area from 1992 – 2006 using occupancy models in program MARK. Occupancy was similar at the Timbered Rock and South Cascades from 1992 – 2002 but occupancy declined rapidly following the Timbered Rock Fire when compared to unburned landscapes at the South Cascades. I also investigated the impacts of fire severity and habitat on occupancy at the Biscuit,

Quartz and Timbered Rock Fires. Occupancy at all 3 fires declined from 2003 – 2006. Initial occupancy was positively influenced by the amount of roosting and foraging habitat with low severity burn within the core (β = 0.08, 95% C.I. = -0.02 – 0.17) and negatively influenced by the amount of hard edge within the core (β = -0.33, 95% C.I. = -0.77 – 0.10). Extinction rates increased in a curvilinear manner as the amount of unsuitable habitat within the core increased (β = 2.15, 95% C.I. = 0.25 – 4.05) and as the amount of edge increased (β = 0.20, 95% C.I. = -0.01 – 0.41). Colonization rates were positively influenced by the amount of nesting, roosting and foraging habitat that received a low severity burn within the core (β = 0.08, 95% C.I. = 0.02 – 0.15).

Demographic surveys were used to determine the number of young fledged per pair of spotted owls. I found no significant differences in productivity of spotted owl pairs in burned landscapes at the Biscuit, Quartz and Timbered Rock Fires and unburned landscapes at the South Cascades. Survival was estimated in program MARK using known fates modeling of radio-telemetry data. Annual survival rates of spotted owls that resided within the fire or had recently emigrated out of the fire were lower (0.64, 95% C.I. = 0.37 – 0.84) than owls that resided outside the fire (1.00, 95% C.I. = 1.00 – 1.00).

Annual home ranges of spotted owls in this study were on average 248.46 ha larger than home ranges observed in the same area prior to wildfire ($t = -2.85$, $df = 32$, $p = 0.01$). However, home ranges of spotted owls that resided inside the fire were not significantly different than owls that resided outside the fire ($t = 0.72$, $df = 18$, $p = 0.48$). Differences in home ranges of individual owls were best explained by the amount of hard edge within the 95% fixed kernel home range. Annual home ranges increased as the amount of hard edge within the home range increased (β = 30.71, SE = 2.65, $p < 0.01$).

Logistic regression was used to assess selection of habitats in relation to early seral forests. Nesting, roosting and foraging habitat with low, moderate or high severity burn was selected by spotted owls in post-fire landscapes. Furthermore, roosting and foraging habitat with a moderate severity burn was also selected. Three habitats were used in a similar manner to early seral forests including; roosting and foraging habitat with low or high severity burn and salvage logged areas. Non-habitat was the only habitat that was commonly avoided. Several abiotic factors were important in determining post-fire habitat selection. Owls selected areas closer to hard edges, perennial streams and lower in elevation than random locations.

Demography and Habitat Selection of Northern Spotted Owls in Post-Fire Landscapes of Southwestern Oregon

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Darren A. Clark, Author

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CHAPTER 1

INTRODUCTION

Darren A. Clark

Historically, one of the most important events that shaped the composition and structure of forests in southwestern Oregon was wildfire (Agee 1993, Aztet and Martin 1994, Sensenig 2002). Frequent low intensity fires with occasional large scale stand replacement events were common (Agee 1993) and created a patchwork of forest stands, opened canopy gaps, and increased forest complexity and species diversity (Agee 1991). This fire regime was maintained due to characteristically hot and dry summers, accompanied by frequent lighting strikes and fires ignited by Native Americans and early European explorers (Agee 1993). This historic fire regime was disrupted when land managers adopted an active fire suppression policy throughout the western United States in the 20th century (Agee 1993).

Through fire suppression, ladder fuels increased and forests became more densely stocked in many areas of the western United States (Agee 1993), as well as parts of southwestern Oregon (Sensenig 2002). This created additional fuel loads in some coniferous forests and increased the likelihood of stand-replacing events (Agee 1993, Taylor and Skinner 1997, Sensenig 2002). While fire suppression may have initially lowered fire frequencies, several major fires (> 25 ha) occurred in 1992, 1994, 2001, 2002, 2005, and 2006 throughout southwest Oregon. This placed many of the forest stands critical to the conservation of northern spotted owls (*Strix occidentalis caurina*) in danger of being consumed by stand-replacing fire (Agee and Edmonds 1992, Agee 1993, Spies et al. 2006).

Currently, much debate surrounds the management of dry forest ecosystems and burned landscapes (Beschta et al. 2004, Noss et al. 2006), with post-fire forest restoration practices being highly controversial (Donato et al. 2006a, Newton et al. 2006, Donato et al. 2006b). The controversy moved into the political arena with the passage of the Healthy Forests Restoration Act of 2003 and the proposal of the Forest Emergency Recovery and Research Act (HR 4200) by the United States Congress. Wildfire is often viewed as a catastrophic event, and the public has become increasingly concerned about wildfire over time (Kauffman 2006), while the ecological benefits of wildfire has gained support among scientists (Agee 1993, Noss et al. 2006). The northern spotted owl has been at the forefront of forest management debates in the Pacific Northwest for over 3 decades (Thomas et al. 1990, Gutiérrez et al. 1996, Noon and Franklin 2002) and will likely play an important role in post-fire land management. Given that spotted owls are a Federally Threatened species (U.S. Fish and Wildlife Service 1990), their post-fire habitat requirements must be considered during land management activities to ensure the long-term conservation of the species.

The prevalence and severity of wildfire may increase within spotted owl habitat due to increased fuel loads created though active fire suppression in some dry forest ecosystems (Agee 1993, Taylor and Skinner 1997, Sensenig 2002). Therefore, it is necessary to develop an understanding of the effects of wildfire on spotted owls, and management decisions should be made to mitigate for the effects of wildfire. However, little knowledge about the impacts of wildfire and subsequent land management activities on spotted owls exists to guide management decisions. Bond et al. (2002) found that short-term impacts (< 1 year) of wildfire on spotted owl survival, reproductive success, and mate/site fidelity were minimal in areas burned by low to moderate severity fires in northern California, Arizona and New Mexico. While the short-term impacts may be minimal, suitable habitat around spotted owl nest sites continued to decline up to 2 years post-fire as additional tree mortality occurred (Gaines et al. 1997). Following wildfire in the eastern Washington Cascades spotted owls utilized areas of low intensity burns (Bevis et al. 1997). In addition, low intensity prescribed fire had little impact on the ability of Mexican spotted owls (*Strix occidentalis lucida*) to reproduce (Sheppard and Farnsworth 1997) and occupancy and productivity of the subspecies in burned landscapes was found to be slightly less than in unburned landscapes (Jenness et al. 2004).

Several large wildfires in southwestern Oregon in 2001 - 2002 provided a unique opportunity to study the impacts of wildfire on spotted owl demography, movements and habitat selection. I investigated the effects of wildfire on spotted owls using radio-telemetry and demographic surveys at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon. Post-fire spotted owl habitat maps were created to investigate the impacts of wildfire and habitat on spotted owl demography and habitat selection. I compared occupancy rates of territories historically occupied by spotted owls in burned and unburned landscapes, and I investigated the effects of fire and habitat covariates on spotted owl occupancy in burned landscapes. In addition, I compared survival rates and productivity of spotted owls in burned and unburned landscapes. Furthermore, I investigated differences in home ranges of owls before and after wildfire and of owls in burned and unburned landscapes. Fire and habitat features were used to investigate differences in home ranges of individual owls. Habitat selection of spotted owls following wildfire was investigated at landscape and territorial scales. Finally, I compared fire severity and forest stand characteristics in stands that were frequently used by spotted owls versus similar stands that were infrequently used.

Results generated from this research provide information to guide management decisions for the conservation of spotted owls in burned landscapes. Understanding the habitat features that are important to spotted owls in burned landscapes will allow for identification and protection of habitat during salvage operations and post-fire rehabilitation efforts. In addition, results from this research may help create prescribed fire treatments in spotted owl habitat to reduce the risk of large-scale, stand replacing fire.

CHAPTER 2

STUDY AREA DESCRIPTIONS AND POST-FIRE HABITAT MAPPING

Darren A. Clark

INTRODUCTION

Three large wildfires in southwest Oregon during the summers of 2001 and 2002 provided the opportunity to investigate the impacts of wildfire on northern spotted owls (*Strix occidentalis caurina*). Demographic surveys were conducted to determine occupancy and reproductive status of 40 historic spotted owl territories at the Biscuit, Quartz and Timbered Rock Fires. Radio-telemetry was used to estimate post-fire home ranges, habitat selection and survival of spotted owls at the Quartz and Timbered Rock Fires. Post-fire habitat maps were created to investigate post-fire habitat selection and demography of spotted owls.

STUDY AREAS

My study was conducted within and around the Biscuit, Quartz, and Timbered Rock Fires in southwestern Oregon (Figure 2.1), which encompassed 3 distinct geographic regions; the mid-Coastal Siskiyou Mountains (Biscuit Fire), the Siskiyou Mountains (Quartz Fire) and the Cascade Mountains (Timbered Rock Fire). Franklin and Dyrness (1973) identified forest types in this region as part of the Mixed-Conifer and Mixed-Evergreen vegetation zones. Common tree species included ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), Douglas-fir (*Psudotsuga menziesii*), incense cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), Oregon white oak (*Quercus garryana*), California black oak (*Quercus kellogii*), tanoak (*Lithocarpus densiflorus*), and Pacific madrone (*Arbutus menziesii*). Southwest Oregon was historically characterized by a frequent low intensity fire regime with occasional stand replacement events (Agee 1993). Climate was characteristically temperate with hot, dry summers and cool, moist winters.

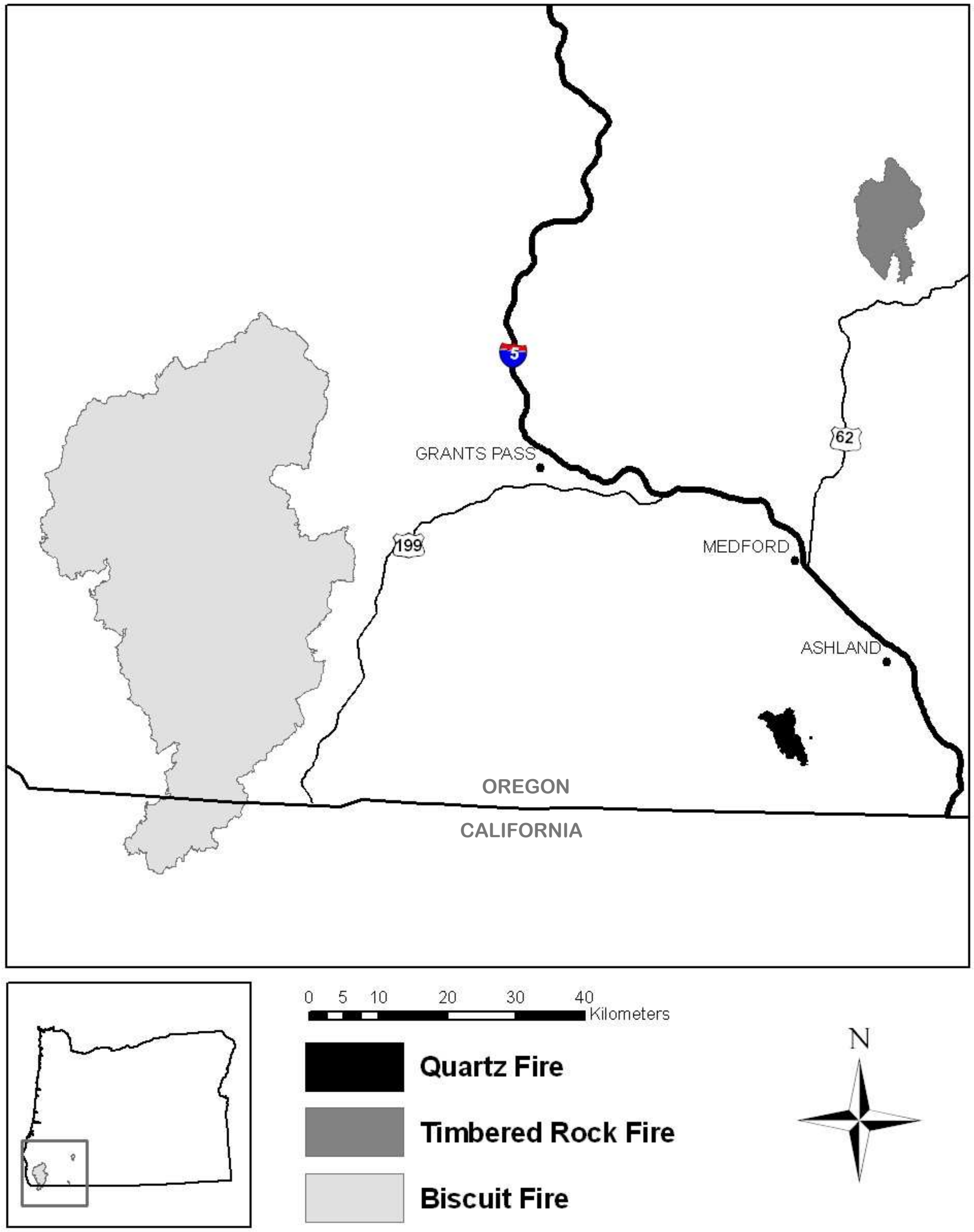

Figure 2.1. Location of the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon.

Biscuit Fire

The Biscuit Fire originated from several small fires, which were ignited by lightning in mid-July 2002. These fires eventually merged into a very large complex fire that covered approximately 201,436 ha of public and private lands. Fifty known spotted owl territories (49 on U.S. Forest Service and 1 on Bureau of Land Management lands) were within or adjacent to the fire boundaries. Demographic surveys were conducted at 9 spotted owl territories on the eastern border of the Biscuit Fire during the 2003 – 2006 breeding seasons. The territories surveyed were within the Briggs Creek, Silver Creek, Deer Creek, and Illinois River watersheds, ranging in elevation from 300 – 1,400 m. The warmest average daily temperatures occurred in July (21.2 °C), and the coldest average daily temperatures were in December (4.4 °C). Rainfall occurred predominately during winter, and average annual rainfall was 113 cm (Oregon Climate Service, Oregon State University, unpublished data).

Quartz Fire

The Quartz Fire ignited during a lightning storm in August, 2001 and burned roughly 2,484 ha of public and private land. The fire burned portions of the Glade Creek, Little Applegate, and Yale Creek watersheds at elevations of approximately 600 – 1,850 m. Rainfall averaged 66 cm per year. The warmest average daily temperatures occurred in July (21.3 °C), and the lowest average daily temperatures occurred in December (3.9 °C) (Oregon Climate Service, Oregon State University, unpublished data). Demographic surveys were conducted at 7 owl territories within the fire and 2 territories at the edge of the fire that were partially burned. All territories were surveyed for 5 years following wildfire from 2002 – 2006. Radio-telemetry was conducted at 1 owl territory within the fire and 1 territory adjacent to the fire from April, 2005 – April, 2006.

Timbered Rock Fire

The Timbered Rock Fire ignited in mid-July, 2002 and burned approximately 11,028 ha of public and private land within the Elk Creek Watershed, at elevations ranging from 450 – 1,350 m. Rainfall averaged 88 cm. The warmest and coldest average daily temperatures occurred in July (21.0 °C) and December (3.4 °C), respectively (Oregon Climate Service, Oregon State University, unpublished data). Demographic surveys were conducted at all 22 known historic spotted owl territories for 4 years following the fire from 2003 – 2006. Spotted owls were monitored with radio-telemetry at 7 territories within the fire and 5 territories immediately adjacent to the fire from September 2004 – August 2006.

HABITAT MAPPING

Habitat maps of each fire were created with identical methodology. Ground plot data were collected and used as training sites in map creation and in accuracy assessment of final map outputs. Within each 15m fixed radius ground plot, I estimated fire severity using a modified composite burn index (CBI) (Key and Benson 1999a), obtained an estimate of canopy closure and measured diameter at breast height (DBH) of dominant trees. Accuracy assessment plots were randomly distributed within the boundary of the study areas. Training plots were non-randomly distributed across the landscape and were collected opportunistically during owl surveys or in large patches of contiguous habitat.

Fire Severity Mapping

Fire severity maps were created using a differenced normalized burn ratio (dNBR) (Key and Benson 1999b) with image processing conducted in ERDAS Imagine (Leica Geosystems Geospatial Imaging, LLC, Norcross, GA, USA). The dNBR

$$dNBR = NBR_{pre\text{-}fire} - NBR_{post\text{-}fire}$$

method was used because the difference of mid-infrared (Band 4) and near-infrared (Band 7) bands provided the greatest contrast of fire effects (Clark 2000), and the normalized ratio of these bands are the most sensitive to differences in fire severity (Lopez-Garcia and Casselles 1991, White et al. 1996). The dNBR was created from a pre-fire Landsat TM image acquired 31 May 2001 and a post-fire image acquired 13 May 2006 (Biscuit and Quartz Fires: Path 046 Row 031, Timbered Rock Fire: Path 046 Row 030).

Prior to the creation of the pre- and post-fire burn ratio indices (NBR),

$$NBR = \frac{\text{Band 4 - Band 7}}{\text{Band 4 + Band 7}}$$

I conducted an atmospheric correction to minimize and remove atmospheric scatter by subtracting brightness values from each image layer, even though atmospheric scatter is minimal in the infrared bands (Avery and Berlin 1992). Images were subset to include relevant portions of the Landsat TM scene to aide in faster image processing. The values of the post-fire NBR image were then differenced from the pre-fire NBR image to obtain an estimate of overstory canopy damage caused by the fire (dNBR image).

The dNBR image was grouped into 3 fire severity classes using a 3 step supervised classification approach: (1) training, (2) classification, and (3) map output (Lillesand et al. 2004:552). Ground plot data were used to identify representative areas of fire severity classes associated with distinct dNBR values. Seed pixels were placed on the coordinates of ground plots and expanded up to 100 pixels using a 4 neighbor region grow function. Spectral signatures of each fire severity class were created from combined seed pixel groups. The spectral signatures were used to classify the dNBR image using a maximum likelihood classifier, which accounted for variance in spectral signatures around the mean. Miller and Yool (2002) found that a 3 class supervised classification produced a more accurate fire severity map than 4 class maps and unsupervised classification methods. I obtained similar results with low and unburned severities being "confused" in a 4 class scheme; therefore, I combined low and unburned severities into 1 class. The classified dNBR image contained many scattered individual pixels. The "salt and pepper" effect was removed with an 8 neighbor clump function and all pixel groupings < 2 ha were sieved to match the size of error polygons associated with telemetry locations. The resulting image was then smoothed using a 7x7 neighborhood function to fill in missing pixel values. The final fire severity map was then converted into a polygon layer and imported into ArcGIS 9.1 (ESRI, Redlands, CA, USA) for analysis.

Spotted Owl Habitat Suitability Mapping

Previously, maps that defined habitat suitability throughout the range of the northern spotted owl were created to assess changes in habitat over time (Davis and Lint 2005). These maps consisted of habitat suitability scores ranging from 0-100, with a pixel resolution of 25 meters. I re-sampled the map to a resolution of 30 meters to match fire severity maps. The habitat map was reclassified into 3 distinct bins based on suitability score distributions and existing knowledge of suitability values associated with nesting habitat of spotted owls.

Within the Klamath and West Cascades provinces, 90% of spotted owls nested in habitats with a suitability score > 50 (Davis and Lint 2005). Therefore, habitats having a suitability score > 50 were defined as nesting, roosting and foraging habitat (NRF). NRF habitats were comprised of mature and older forests. Within the West Cascades and Klamath provinces, NRF habitats had quadratic mean diameters of 71.1 cm (SE = 3.5 cm) and 68.5 cm (SE = 4.5 cm), respectively. Visual inspection of habitat suitability distributions identified a natural break at a value of 25, which defined the cutoff between early seral habitat (suitability score < 25), and roosting and foraging habitat (RF) (suitability scores of 26 – 50). Early seral stands included sapling and pole sized trees and RF habitats included intermediate seral stage trees. Stands with habitat suitability scores of 26 – 50 in the West Cascades and Klamath provinces had quadratic mean diameters of 33.3 cm (SE = 4.1 cm) and 30.3 cm (SE = 4.29 cm), respectively. Quadratic mean diameter of stands within the West Cascades and Klamath provinces with suitability scores < 25 were 12.3 cm (SE = 1.8 cm) and 10.4 cm (SE = 1.2 cm), respectively. This breakdown was approved by the creators of the original map (personal communication, Ray Davis and Joe Lint 2006) and matched existing knowledge of habitats within the study areas. Non-habitat areas are comprised of non-forested areas, water, and serpentine soils. These areas were identified on the original map and preserved in my mapping routine. As with the fire severity map, the 3 class habitat suitability map had many scattered individual pixels and was rectified using the same methods. The final habitat suitability map was then exported as a polygon layer in ArcGIS 9.1.

Mapping Salvage Logged Stands

To account for post-fire timber harvest, I obtained GIS data of salvage unit boundaries. In the event that salvage data were not provided, I obtained pre- and post-fire aerial photos to identify forest stands that had been harvested following wildfire and manually digitized harvest unit boundaries in ArcGIS 9.1. Salvage unit polygons included a variety of harvest techniques including clear-cuts, thinning with green tree retention, and patches of wildlife “leave” trees. However, to minimize the number of habitat classes in the final map, harvest prescriptions were combined into a single category, regardless of the type of salvage.

Final Post-Fire Spotted Owl Habitat Map

The final post-fire habitat map was created by merging; (1) the fire severity map, (2) the pre-fire owl habitat suitability map, and (3) the boundaries of salvage logged areas in ArcGIS 9.1. This resulted in 9 distinct post-fire habitat classes (Table 2.1), with a minimum mapping unit of 2 ha. Overall map accuracies were assessed using data from ground plots and were 68.1% for the Timbered Rock Fire, 68.8% for the Biscuit Fire and 74.6% for the Quartz Fire. Accuracies of individual classes varied considerably (Table 2.2). Most misclassified data points were within 1 habitat or fire severity class of the actual habitat type (Appendix A). Seventeen of 20 (85%) misclassified ground plots at the Biscuit Fire, 10 of 15 (67%) at the Quartz Fire, and 11 of 22 (50%) at the Timbered Rock Fire were within 1 habitat or fire severity class of the correct classification. Based on these estimates, overall map accuracy within 1 habitat or fire severity class was 95.3% at the Biscuit Fire, 91.5% at the Quartz Fire, and 84.1% at the Timbered Rock Fire.

Table 2.1. Habitat classification definitions for maps used to assess the impacts of wildfire on northern spotted owls at the Biscuit, Quartz and Timbered Rock Fires, Oregon, USA.

Habitat Class	Description
Non-Habitat	Non-forested areas including; water, meadows and serpentine soils.
Early Seral	Early seral and pole sized stands.
Roosting and Foraging (RF) - Low/Unburned Severity Burn	Intermediate seral stages with ≤ 20% of the overstory removed by fire.
Roosting and Foraging (RF) - Moderate Severity Burn	Intermediate seral stages with 21 - 70% of the overstory removed by fire.
Roosting and Foraging (RF) - High Severity Burn	Intermediate seral stages with > 70% of the overstory removed by fire.
Nesting, Roosting, and Foraging (NRF) - Low/Unburned Severity Burn	Mature and older forests with ≤ 20% of the overstory removed by fire.
Nesting, Roosting, and Foraging (NRF) - Moderate Severity Burn	Mature and older forests with 21 - 70% of the overstory removed by fire.
Nesting, Roosting, and Foraging (NRF) - High Severity Burn	Mature and older forests with > 70% of the overstory removed by fire.
Salvage	Timberlands that received post-fire timber harvest, including; clear cuts, thinning, and patches of leave trees.

Table 2.2. Accuracy assessment matrix of the 9 class post-fire spotted owl habitat map of the Biscuit, Quartz and Timbered Rock Fires, used to assess the impacts of wildfire on northern spotted owls.

Timbered Rock Fire

Habitat Class	Reference Total	Classification Total	Number Correct	Producers Accuracy	Users Accuracy
Non-Habitat	2	2	2	100.00	100.00
Early Seral	11	11	6	54.55	54.55
Roosting and Foraging - Low/Unburned Severity Burn	8	7	4	50.00	57.14
Roosting and Foraging - Moderate Severity Burn	4	2	2	50.00	100.00
Roosting and Foraging - High Severity Burn	4	5	3	75.00	60.00
Nesting, Roosting and Foraging - Low/Unburned Severity Burn	19	18	14	73.68	77.78
Nesting, Roosting and Foraging - Moderate Burn	9	9	6	66.67	66.67
Nesting, Roosting and Foraging - High Burn	7	6	5	71.43	83.33
Salvage Logged	5	9	5	100.00	55.56
Total	69	69	47		

Overall Timbered Rock Fire Map Accuracy = 68.12%

Quartz Fire

Habitat Class	Reference Total	Classification Total	Number Correct	Producers Accuracy	Users Accuracy
Non-Habitat	0	0	0	NA	NA
Early Seral	11	11	10	90.91	90.91
Roosting and Foraging - Low/Unburned Severity Burn	6	6	4	66.67	66.67
Roosting and Foraging - Moderate Severity Burn	5	2	0	0.00	0.00
Roosting and Foraging - High Severity Burn	3	2	2	66.67	100.00
Nesting, Roosting and Foraging - Low/Unburned Severity Burn	13	14	11	84.62	78.57
Nesting, Roosting and Foraging - Moderate Burn	8	7	5	62.50	71.43
Nesting, Roosting and Foraging - High Burn	9	13	8	88.89	61.54
Salvage Logged	4	4	4	100.00	100.00
Total	59	59	44		

Overall Quartz Fire Map Accuracy = 74.58%

Table 2.2 Continued….

Biscuit Fire					
Habitat Class	Reference Total	Classification Total	Number Correct	Producers Accuracy	Users Accuracy
Non-Habitat	7	7	6	85.71	85.71
Early Seral	7	5	4	57.14	80.00
Roosting and Foraging - Low/Unburned Severity Burn	7	8	4	57.14	50.00
Roosting and Foraging - Moderate Severity Burn	5	8	4	80.00	50.00
Roosting and Foraging - High Severity Burn	8	5	4	50.00	80.00
Nesting, Roosting and Foraging - Low/Unburned Severity Burn	14	13	11	78.57	84.62
Nesting, Roosting and Foraging - Moderate Burn	6	7	4	66.67	57.14
Nesting, Roosting and Foraging - High Burn	7	7	4	57.14	57.14
Salvage Logged	3	4	3	100.00	75.00
Total	64	64	44		

Overall Biscuit Fire Map Accuracy = 68.75%

Mapping Edge Habitat

Polygon layers of post-fire habitat maps were imported into ArcGIS 9.1 and converted into suitable and non-suitable habitat. Suitable habitat included low/unburned and moderately burned RF and NRF habitats. Non-suitable habitat included non-habitat, early-seral habitat, high severity burns and salvage logged areas. The interface between suitable and non-suitable habitat was defined as hard edge and I created a polyline layer in ArcGIS 9.1 to represent the boundary between these 2 habitats.

CHAPTER 3

OCCUPANCY RATES OF NORTHERN SPOTTED OWLS IN POST-FIRE LANDSCAPES OF SOUTHWESTERN OREGON

Darren A. Clark

INTRODUCTION

Northern spotted owls (*Strix occidentalis caurina*, hereafter spotted owl) are a medium sized, forest-dwelling raptor with high levels of mate and site fidelity (Forsman et al. 1984, 2002, Thomas et al. 1990, Zimmerman et al. 2007). Their nesting territories are usually comprised of greater proportions of mature and old forest than the surrounding landscape (Ripple et al. 1991, 1997, Lemkuhl and Raphael 1993, Swindle et al. 1999). Furthermore, forest stands used by spotted owls usually have large proportions of down woody debris and snags, high canopy closure, and high structural diversity (Forsman et al. 1984, Thomas et al. 1990, Hershey et al. 1998, North et al. 1999, Irwin et al. 2000). Some of the structural complexity in forest stands occupied by spotted owls in southwestern Oregon may have developed in the absence of wildfire due to active fire suppression during the latter part of the 20th century (Agee 1993). As a result of active fire suppression, increased fuel loads may have created a large scale risk of stand replacing fires (Agee and Edmonds 1992) and potentially reduced the sustainability of spotted owl habitat in dry forest ecosystems (Agee 1993, Taylor and Skinner 1997, Spies et al. 2006).

After the harvest of older conifer forests were largely halted on federal lands within the Pacific Northwest in the late 1980's, wildfire has become the leading cause of spotted owl habitat loss on federal lands within the range of the northern spotted owl (Davis and Lint 2005). This has caused the sustainability of owl populations in dry forest ecosystems to be questioned (Spies et al. 2006). However, information on occupancy of historical territories by spotted owls after fires is lacking to inform land managers about the impacts of wildfire on spotted owl populations. Bond et al. (2002) found minimal short-term changes (<1 yr) in spotted owl survival and mate/site fidelity following wildfire in low to moderate severity burns in northern California, which suggests that occupancy may not be affected by wildfire. Furthermore, occupancy of Mexican spotted owls (*Strix occidentalis lucida*) in burned landscapes was similar to unburned landscapes (Jenness et al. 2004). Suitable habitat surrounding spotted owl nest sites continued to decline 2 years post-fire as additional tree mortality occurred (Gaines et al. 1997), which may cause the impacts of wildfire to be extended over a longer time period.

The greatest impact of wildfire on spotted owls will likely be the destruction or alteration of habitat. Numerous studies have documented that spotted owl survival and occupancy were positively associated with increased amounts of late-successional forest (Franklin et al. 2000, Olson et al. 2004, Blakesley et al. 2005, Dugger et al. 2005). Therefore, large scale wildfires that destroy habitat may negatively impact spotted owl survival and occupancy. If wildfire removes a sufficient amount of suitable habitat, owl territories will likely be abandoned (Bart and Forsman 1992, Bart 1995), and these areas likely will not support owls until mature and older forests are restored.

Understanding the effects of wildfire on occupancy of historical nesting territories is essential to ensure the long-term conservation of spotted owls in dry forest ecosystems where wildfires are common. Many spotted owl populations continue to decline despite the lack of timber harvest on federally administered lands (Anthony et al. 2006). While loss of habitat to wildfire throughout the range of the spotted owl is consistent with predicted losses, the loss of habitat in dry forest ecosystems is exceeding predictions (Davis and Lint 2005). For the recovery of spotted owls to be effective, the effects of wildfires on spotted owls should be incorporated in management plans, as wildfire will continue to be prevalent in dry forest ecosystems.

The purpose of this study was to investigate the short-term impacts of wildfire on spotted owl site occupancy. I predicted that (1) occupancy would decline following the Timbered Rock Fire when compared to unburned landscapes, (2) occupancy would decline as the amount of high severity fire and salvage logging increased within territories and (3) occupancy would be higher at territories with greater amounts of mature and older forest with low severity burn.

METHODS

Spotted Owl Demography Surveys

Demographic surveys were conducted annually between 1 March and 31 August to describe occupancy of spotted owl territories according to established protocols (Lint et al. 1999). Surveys were conducted as a collaborative effort between the Oregon Cooperative Wildlife Research Unit (OCWRU), the Bureau of Land Management (BLM), the United States Forest Service (USFS) and private timber companies at 40 historic owl territories at 3 fires in southwestern Oregon (Appendix B). Twenty-two territories at the Timbered Rock Fire and 9 territories at the Biscuit Fire were surveyed during the 2003 – 2006 breeding seasons. Nine historic territories were surveyed at the Quartz Fire during the 2002 – 2006 breeding seasons. All 22 owl territories at the Timbered Rock Fire had been surveyed prior to wildfire from 1992 – 2002 and served as a comparison of pre- and post-fire occupancy. In addition, surveys were conducted at the South Cascades Demography Area (South Cascades) from 1992 – 2006 by the OCWRU as part of the range-wide monitoring program for spotted owls (Lint et al. 1999, Anthony et al. 2006). This information was used as a comparison of occupancy rates between burned and unburned landscapes.

Occupancy

Demographic survey data were used to create site-specific detection histories according to guidelines established by Olson et al. (2005). In contrast to Olson et al. (2005), I created detection histories for owl pairs, rather than individuals and pairs. I took this approach because owl pairs were the biological unit of interest and provide the most relevant information on post-fire occupancy rates. While individual owl occupancy may represent an upper threshold of occupancy levels, individuals are not capable of producing offspring. Therefore owl pairs represent the reproductive component of the population.

Site occupancy was estimated using open population occupancy models (MacKenzie et al. 2003, 2006) in program MARK (White and Burnham 1999). This analysis generated estimates of 4 parameters: Ψ, the probability that a site is occupied in the first year of the study (initial occupancy), γ, the probability of an unoccupied site being colonized in each subsequent year (colonization), ε, the probability of an occupied site going extinct in each subsequent year (extinction), and, p, the probability of detection among and within years (detection). This modeling framework is flexible and allows for constraints on time-specific parameter estimates, the inclusion of site-specific covariates, the ability to model missing observations, the direct estimation of colonization and extinction parameters, and it does not assume detection probabilities are 1.0 (MacKenzie et al. 2003, 2006).

Occupancy estimates were generated using maximum likelihood estimation in program MARK, which optimized model parameters and model fit based upon the data (White and Burnham 1999). Akaike's Information Criterion corrected for small sample sizes (AIC_c) and Akaike weights were used for model selection (Burnham and Anderson 2002). The model with the lowest AIC_c was considered the best (most parsimonious), and models within 2 AIC_c units of the best model were considered competitive (Burnham and Anderson 2002). The model with the lowest AIC_c was used to interpret results, and estimates of initial occupancy, extinction, colonization and detection probabilities were reported from the best model.

Basic Modeling Structure

I developed several *a priori* hypotheses about within-year detection probabilities that included: constant detection (.), linear (T) and curvilinear (lnT) trends. Time-specific models (t) were not considered because they required too many parameters to obtain reasonable estimates (Olson et al. 2005). Quadratic effects (TT) were not considered because I could not develop a biological reason for this relationship to occur with spotted owls. Differences in detection probabilities were considered between study areas, because experience and effort of survey personnel may have differed between areas. Detection probabilities among years, extinction and colonization were modeled to include time specific (t), linear (T), quadratic (TT), and curvilinear (lnT) trends and constant (.) effects. Furthermore, extinction and colonization were hypothesized to vary between study areas, so I considered combinations of area and time where appropriate. I considered 2 hypotheses for initial occupancy that contrasted differences between study areas and constant initial occupancy.

I conducted 2 separate occupancy analyses. In the first analysis, I compared long-term trends in occupancy at Timbered Rock and the South Cascades from 1992 – 2006 to determine if post-fire extinction and colonization rates at the Timbered Rock Fire were different than unburned landscapes at the South Cascades during the same time period. Ten hypotheses (models) were developed to represent ways spotted owls might respond to wildfire. The names and visual representations of these models (Structure 1 – 10) are described in Figure 3.1, and models are referred to by the number of the model throughout this chapter.

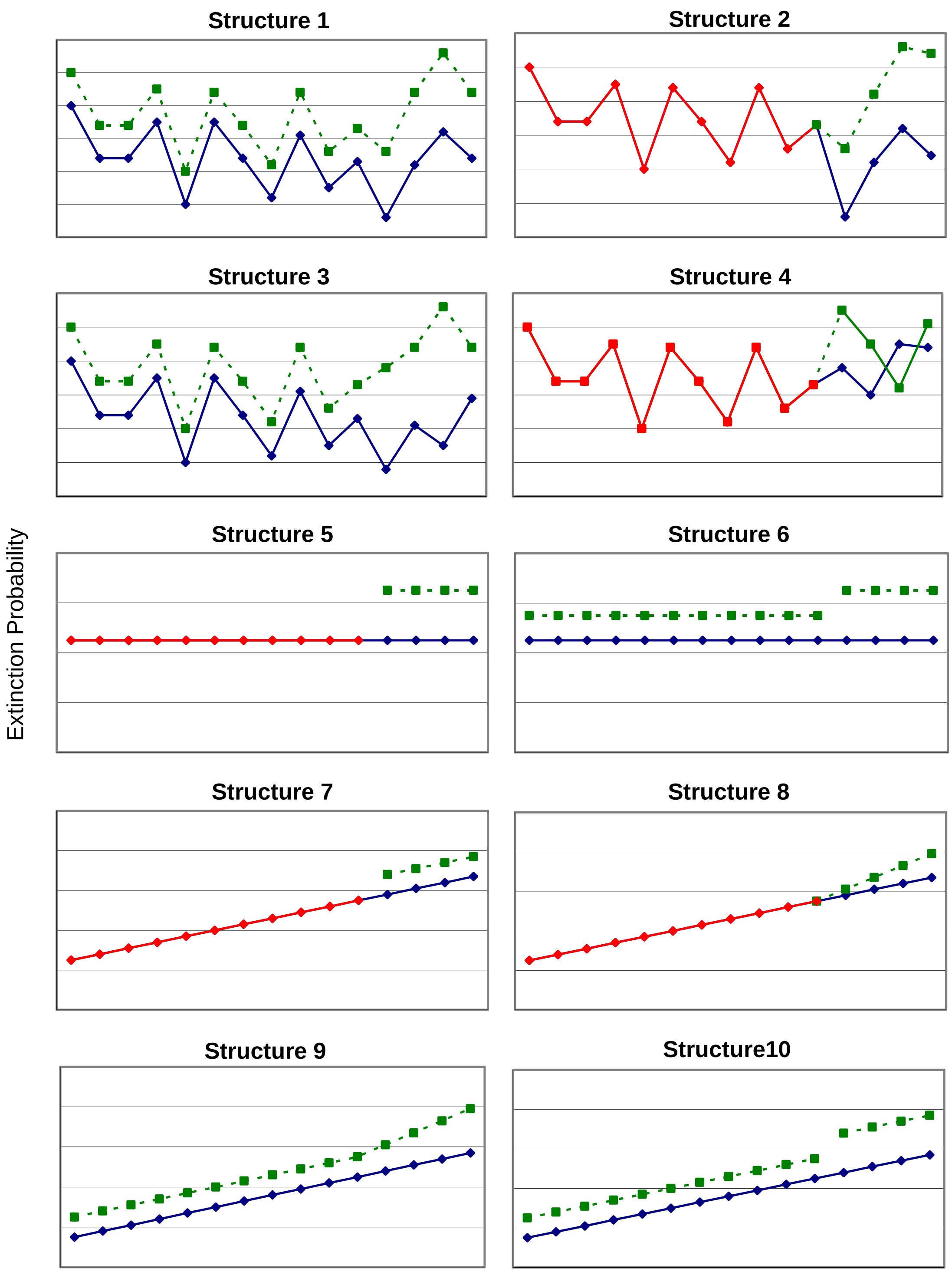

Figure 3.1. Visual representation of 10 hypothetical models comparing extinction rates of owl territories at the Timbered Rock Fire and the South Cascades Demography Area. Red lines indicate no differences between study areas, green-dashed lines represent Timbered Rock, and blue lines represent the South Cascades. The last 4 intervals are post-fire sampling periods which represent potential changes in post-fire extinction rates at Timbered Rock.

I also compared post-fire occupancy from 2003 – 2006 at the Biscuit, Quartz and Timbered Rock Fires. In addition to the hypothesis that differences in occupancy existed between all 3 fires, I hypothesized that the Quartz and Timbered Rock Fires would be similar but the Biscuit Fire may be different because it had the least amount of salvage logging. I also hypothesized that the Quartz Fire may be different than the Timbered Rock and Biscuit Fires because it occurred 1 year prior to the other fires. Finally, I hypothesized that the Quartz and Biscuit Fires would be similar but different than the Timbered Rock Fire because the latter was dominated by a checkerboard land ownership pattern not observed at the Biscuit and Quartz Fires.

The analysis of occupancy at the 3 fires from 2003 – 2006 also included site-specific habitat and fire severity covariates to examine the effects of wildfire on extinction, colonization and initial occupancy. Site-specific covariates were calculated at 2 scales (home range and core area) and with 2 relationships (linear and pseudo-threshold), which represented 4 possible models of each covariate. Covariate values were calculated in ArcGIS 9.1 (ESRI, Redlands, CA, USA) from post-fire owl habitat suitability maps (see Chapter 2) as the percent of each cover type within a 2,230 m radius circle (1560 ha; home range scale) and a 730 m radius circle (167 ha; core area scale) (Appendix C). These scales followed the approach of Dugger et al. (2005) for this geographic region.

I used site-specific covariates with the best non-covariate model structure to assess which form of the covariate best explained the relationship with initial occupancy, extinction and colonization. *A priori* hypotheses regarding the effects of individual covariates varied between covariates and parameters (Table 3.1). After determining the covariate form that best explained the relationship between the covariate and initial occupancy, extinction and colonization, I combined the best form of several individual covariates to test specific *a priori* hypotheses (Appendix D).

Table 3.1. *A priori* hypotheses regarding the effects of habitat-specific covariates on initial occupancy (Ψ), extinction (ε) and colonization (γ) at the Biscuit, Quartz and Timbered Rock Fires in southwest Oregon from 2003 - 2006.

	Effect of Increasing Covariate Value		
Covariate[a]	Ψ	ε	γ
EARLY	Negative	Positive	Negative
RFL	Negative	Positive	Negative
RFM	Negative	Positive	Negative
RF	Negative	Positive	Negative
NRFL	Positive	Negative	Positive
NRFM	Positive	Negative	Positive
NRF	Positive	Negative	Positive
SALV	Negative	Positive	Negative
LOW	Positive	Negative	Positive
MOD	Negative	Positive	Negative
HIGH	Negative	Positive	Negative
HIMOD	Negative	Positive	Negative
SUIT	Positive	Negative	Positive
UNSUIT	Negative	Positive	Negative
LOST	Negative	Positive	Negative
EDGE	Negative	Positive	Negative

[a] EARLY - early seral forest.
RFL - Roosting and foraging habitat that received a low severity burn.
RFM - Roosting and foraging habitat that received a moderate severity burn.
RF - Combined low and moderate severity roosting and foraging habitat.
NRFL - Nesting, roosting and foraging habitat that received a low severity burn.
NRFM - Nesting, roosting and forating habitat that received a moderate severity burn.
NRF - Combined low and moderate severity nesting, roosting, and foraging habitat.
SALV - Forested areas that received post-fire timber harvest.
LOW - Suitable owl habitat (RF and NRF) that received a low severity burn.
MOD - Suitable owl habitat (RF and NRF) that received a moderate severity burn.
HIGH - Suitable owl habitat (RF and NRF) that received a high severity burn.
HIMOD - Combined moderate and high severity (MOD and HIGH).
SUIT - Combined suitable owl habitats (RFL, RFM, NRFL, NRFM).
UNSUIT - Combined unsuitable owl habitats (EARLY, HIGH, SALV).
LOST - Combined high severity fire and salvage logged areas (HIGH and SALV).
EDGE - Length (km) of edge habitat.

RESULTS

Comparison of the South Cascades to Timbered Rock

The best model comparing occupancy at South Cascades and Timbered Rock from 1992 - 2006 was Ψ(Area) ε(Structure 1) γ(Area + T) p(Year, Area + lnT) (Table 3.2) Detection probabilities varied among years and followed a curvilinear trend within years. In most years (9 out of 15), detection probabilities were higher early in the survey season and then declined curvilinearly. Three of the 9 beta coefficients overlapped 0, which indicated the trend was not strong in all years. In the remaining 6 years the detection probabilities were lower early in the survey season and then increased curvilinearly. Three of the 6 beta coefficients overlapped 0 and indicated that the trend was not strong in all years. The best model indicated that initial occupancy was higher at the South Cascades (β = 2.21, 95% C.I. = 0.65 – 3.76) and was estimated to be 0.94 (95% C.I. = 0.88 – 1.00) in 1992 at the South Cascades compared to 0.65 at Timbered Rock (95% C.I. = 0.44 – 0.86). Extinction rates varied by year and study area (ε(Structure 1)), but study areas followed the same pattern over time (Figure 3.2). Extinction rates were lowest at Timbered Rock prior to fire but substantially increased following wildfire (β = 1.46, 95% C.I. = 0.29 – 2.62) and South Cascades had intermediate extinction rates (β = 0.69, 95% C.I. = -0.06 – 1.43). Colonization rates were greater at the South Cascades (β = 1.31, 95% C.I. = 0.60 – 2.03) and declined linearly over time (β = -0.06, 95% C.I. = -0.12 – 0.00) at both study areas (Figure 3.3). Wildfire did not appear to influence post-fire colonization rates at Timbered Rock because models that included differences in post-fire colonization (Figure 3.1) were not competitive with the best model (Table 3.2).

Table 3.2. Model selection results from open population models comparing occupancy, extinction and colonization of the South Cascades Demographic Study Area to the Timbered Rock Fire Study Area in southwest Oregon from 1992 - 2006. For all extinction and colonization models the best model for initial occupancy was Ψ(Area) and detection probabilities was p(Year, Area + lnT)

Model	AICc	ΔAICc	Weight	K[b]	Deviance
{ε(Structure1[a]) γ(Area+T)}	8689.470	0.000	0.414	66	8552.270
{ε(Structure2) γ(Area+T)}	8691.001	1.531	0.193	65	8555.960
{ε(t) γ(Area+T)}	8691.310	1.840	0.165	64	8558.424
{ε(Area+t) γ(Area+T)}	8692.585	3.115	0.087	65	8557.544
{ε(Structure3) γ(Area+T)}	8692.770	3.300	0.080	69	8549.081
{ε(Structure4) γ(Area+T)}	8694.303	4.833	0.037	68	8552.780
{ε(Stucture6) γ(Area+T)}	8698.421	8.951	0.005	53	8589.081
{ε(Stucture9) γ(Area+T)}	8699.932	10.463	0.002	54	8588.465
{ε(Stucture5) γ(Area+T)}	8700.107	10.637	0.002	52	8592.893
{ε(Area*t) γ(Area+T)}	8700.126	10.657	0.002	78	8536.830
{ε(.) γ(Area+T)}	8700.249	10.779	0.002	51	8595.158
{ε(Area*t) γ(Area+TT)}	8702.153	12.683	0.001	79	8536.664
{ε(Area*t) γ(Structure10)}	8702.285	12.816	0.001	79	8536.797
{ε(Area*t) γ(Structure9)}	8702.317	12.848	0.001	79	8536.829
{ε(Area*t) γ(Structure6)}	8703.018	13.548	0.000	78	8539.721
{ε(Area*t) γ(Structure8)}	8708.471	19.002	0.000	79	8542.983
{ε(Area*t) γ(Structure5)}	8709.716	20.246	0.000	77	8548.608
{ε(Area*t) γ(Structure7)}	8711.730	22.260	0.000	78	8548.433
{ε(Area*t) γ(TT)}	8715.644	26.174	0.000	78	8552.347
{ε(Area*t) γ(.)}	8715.714	26.245	0.000	76	8556.793

[a] Visual representation of model structure is given in Figure 3.1.

[b] Number of parameters

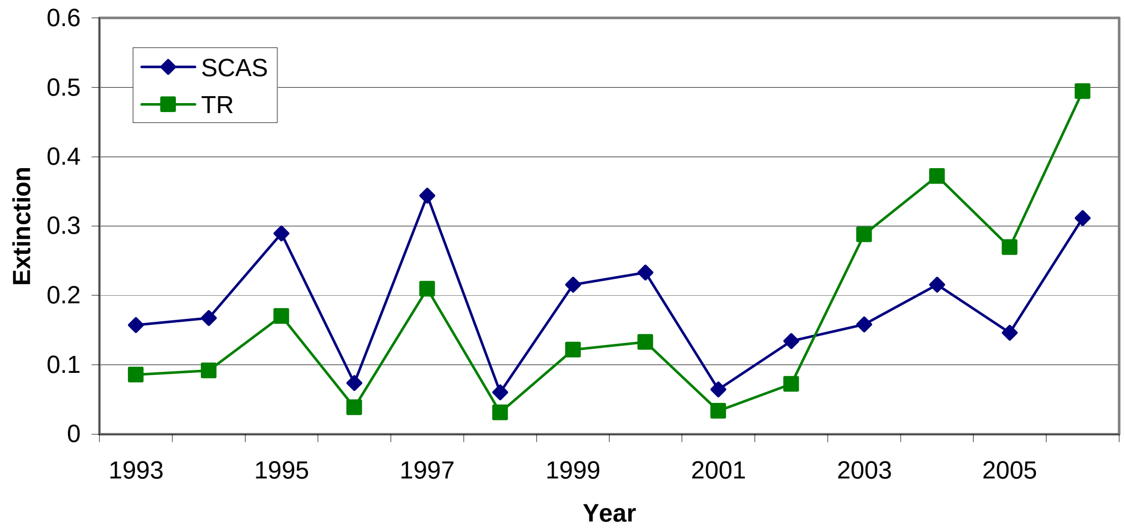

Figure 3.2. Estimated rates of site extinction at the Timbered Rock and South Cascades Study Areas from 1992 – 2006 from model Ψ(Area) ε(Structure1) γ(Area + T) p(Year, Area + lnT). Last 4 years indicate elevated post-fire extinction rates at Timbered Rock.

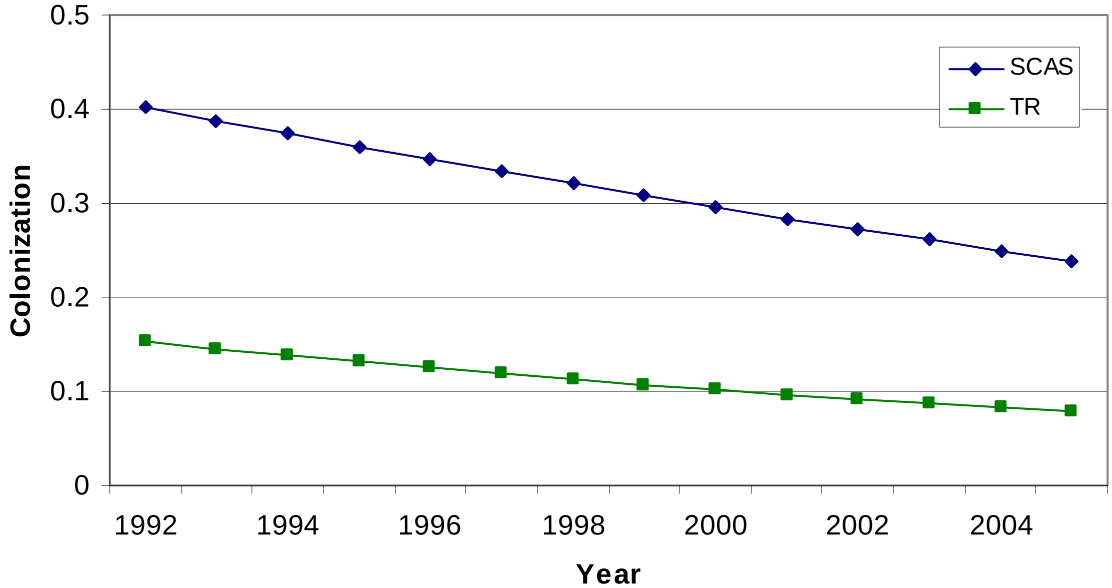

Figure 3.3. Estimated rates of site colonization at the Timbered Rock and South Cascades Study Areas from 1992 – 2006 from model Ψ(Area) ε(Structure1) γ(Area + T) p(Year, Area + lnT).

Two models were competitive with the top model but were identical except for the structure of extinction probabilities. The first competing model suggested that extinction varied by year, was the same at the Timbered Rock and South Cascades from 1992 – 2002, but increased at Timbered Rock from 2003 – 2006 (β = 0.79, 95% C.I. = -0.11 – 1.70), although the confidence interval narrowly overlapped 0. The second competing model suggested that extinction probabilities varied by year (t) but there were no differences in extinction between study areas. The top model suggested significant differences between study areas and had a better fit to the data, as demonstrated by the lower deviance. Furthermore, the top model had over 2 times the weight of competing models even though most of the model structure was similar, which provided additional support for the top model. The summed Akaike weight of the top 3 models was 0.77, which indicated that the model structure on initial occupancy, colonization and detection parameters fit the data well.

Derived occupancy estimates from program Mark indicated that occupancy at South Cascades declined from 1992 – 1994, remained relatively stable from 1995 – 2005, and declined again in 2006 (Figure 3.4). Occupancy at Timbered Rock declined slightly from 1992 – 2002, but declined in an almost linear fashion following wildfire. Only 20% of territories were occupied by a pair of owls in 2006. These results likely indicated that habitat loss attributable to wildfire and subsequent salvage logging caused declines in occupancy following wildfire, not observed in unburned landscapes.

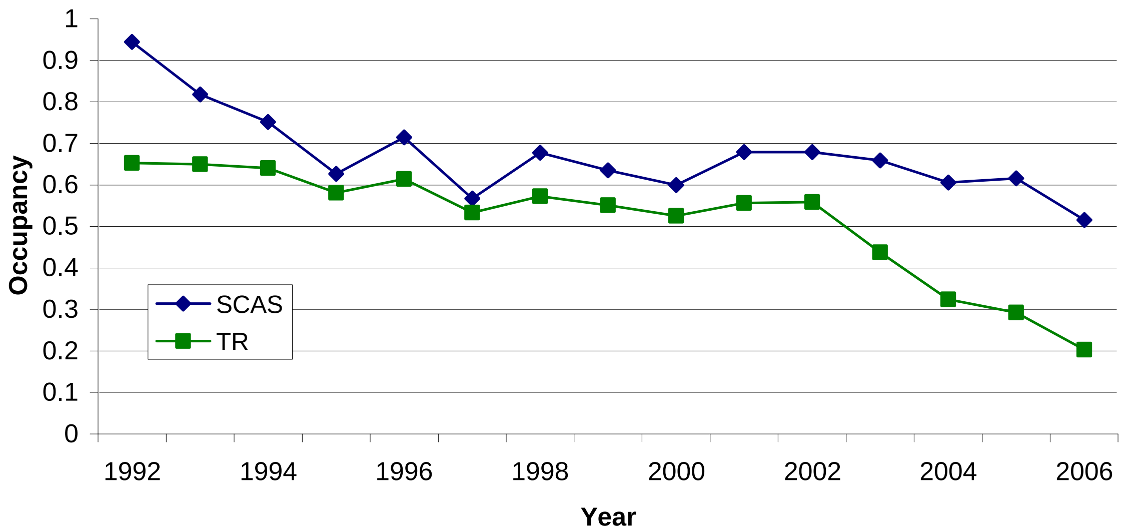

Figure 3.4. Derived estimates of site occupancy probabilities at the Timbered Rock and South Cascades Study Areas from 1992 – 2006 from model Ψ(Area) ε(Structure1) γ(Area + T) p(Year, Area + lnT). Last 4 years indicate declines in post-fire occupancy rates at Timbered Rock.

Influence of Wildfire on Post-Fire Occupancy

The best model that described post-fire occupancy using habitat specific covariates was *Ψ*(RFLc + EDGEc) *ε*(BIS,TR=Q + T + lnUNSUITc + EDGEhr) *γ*(NRFLc + lnHIGHhr) *p*(.,.) (Table 3.3). This model indicated that detection probabilities were constant among study areas, years, and within years. Initial occupancy was similar among study areas, but influenced by the amount of roosting and foraging habitat with low severity burn within the core area and the amount of hard edge within the core. Extinction rates were equal at the Timbered Rock and Quartz Fires but greater at the Biscuit Fire and followed a linear trend over time at all study areas. Furthermore, extinction was influenced by the amount of unsuitable habitat in the core and the amount of edge within the home range scale. Colonization rates were similar among study areas but impacted by the amount of nesting, roosting and foraging habitat within the core and the amount of high severity wildfire within the home range.

Table 3.3. Model selection results for open population occupancy models using habitat specific covariates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 - 2006.

Model	AICc	ΔAICc	Weight	K	Deviance
Best Overall Model					
{Ψ(RFLc+EDGEc) ε(BIS,TR=Q+T+lnUNSUITc+EDGEhr) γ(NRFLc+lnHIGHhr) p(.,.)}	446.135	0.000	0.295	12	419.998
{Ψ(.) ε(BIS,TR=Q+T) γ(.) p(.,.)}	476.930	30.795	0.000	6	464.377
Initial Occupancy					
{Ψ(RFLc+EDGEc) ε(BIS,TR=Q+T) γ(.) p(.,.)}	473.473	0.000	0.073	8	456.513
{Ψ(RFLc) ε(BIS,TR=Q+T) γ(.) p(.,.)}	474.040	0.567	0.055	7	459.298
{Ψ(EDGEc) ε(BIS,TR=Q+T) γ(.) p(.,.)}	474.464	0.990	0.044	7	459.722
{Ψ(lnRFLc) ε(BIS,TR=Q+T) γ(.) p(.,.)}	474.703	1.230	0.039	7	459.961
{Ψ(RFc) ε(BIS,TR=Q+T) γ(.) p(.,.)}	474.933	1.460	0.035	7	460.191
{Ψ(EDGEc+EDGE2c) ε(BIS,TR=Q+T) γ(.) p(.,.)}	475.578	2.104	0.025	8	458.618
{Ψ(.) ε(BIS,TR=Q+T) γ(.) p(.,.)}	476.930	3.457	0.013	6	464.377
Extinction					
{Ψ(.) ε(lnUNSUITc+EDGEhr) γ(.) p(.,.)}	464.614	0.000	0.244	8	447.654
{Ψ(.) ε(lnUNSUITc) γ(.) p(.,.)}	466.503	1.888	0.095	7	451.761
{Ψ(.) ε(NRFLc+lnUNSUITc) γ(.),p(.,.)}	467.510	2.895	0.057	8	450.550
{Ψ(.) ε(BIS,TR=Q+T) γ(.) p(.,.)}	476.930	12.315	0.001	6	464.377
Colonization					
{Ψ(.) ε(BIS,TR=Q+T) γ(NRFLc+lnHIGHhr) p(.,.)}	460.711	0.000	0.135	8	443.751
{Ψ(.) ε(BIS,TR=Q+T) γ(lnNRFc+lnHIGHhr) p(.,.)}	461.436	0.725	0.094	8	444.476
{Ψ(.) ε(BIS,TR=Q+T) γ(lnRFc+lnNRFc+lnHIGHhr) p(.,.)}	461.984	1.273	0.072	9	442.776
{Ψ(.) ε(BIS,TR=Q+T) γ(NRFLc+NRFMhr+lnHIGHhr) p(.,.)}	462.270	1.559	0.062	9	443.062
{Ψ(.) ε(BIS,TR=Q+T) γ(NRFLc+lnHIGHhr+SALVc) p(.,.)}	462.594	1.883	0.053	9	443.386
{Ψ(.) ε(BIS,TR=Q+T) γ(RFLc+NRFLc+lnHIGHhr) p(.,.)}	462.628	1.916	0.052	9	443.420
{Ψ(.) ε(BIS,TR=Q+T) γ(LOWc+lnMODc+lnHIGHhr) p(.,.)}	462.817	2.106	0.047	9	443.609
{Ψ(.) ε(BIS,TR=Q+T) γ(.) p(.,.)}	476.930	16.219	0.000	6	464.377

Detection Probabilities

Habitat covariates were not included in detection probability models because I did not hypothesize that habitat and fire severity would influence detection probabilities of spotted owls. There were no competing models with the best detection probability model, which indicated that detection probabilities were constant among and within years and did not differ among study areas.

Initial Occupancy

Four models were considered competing with the best initial occupancy model structure Ψ(RFLc + EDGEc) (Table 3.3, Appendix E), but all competing models were variations of the top model and were not considered further because the top model had a better fit. Initial occupancy was positively associated with the amount of roosting and foraging habitat with low severity burn within the core (β = 0.08, 95% C.I. = -0.02 – 0.17) (Figure 3.5). There was also evidence that increased amounts of edge habitat within the core negatively influenced initial occupancy (β = -0.33, 95% C.I. = -0.77 – 0.10) (Figure 3.6) but the relationship was not strong because the confidence interval overlapped 0.

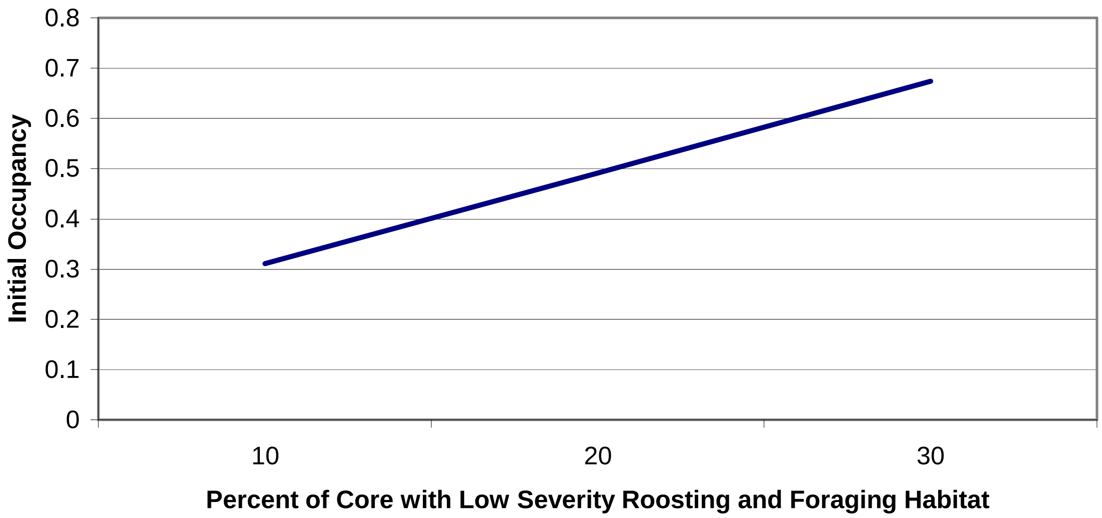

Figure 3.5. The effect of roosting and foraging habitat with a low severity burn on initial occupancy at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 – 2006. Estimates generated from model Ψ(RFLc + EDGEc) ε(BIS,TR=Q + T + lnUNSUITc + EDGEhr) γ(NRFLc + lnHIGHhr) p(.,.) using equation logit (Ψ) = 0.587 + 0.076(RFLc) – 0.332(EDGEc).

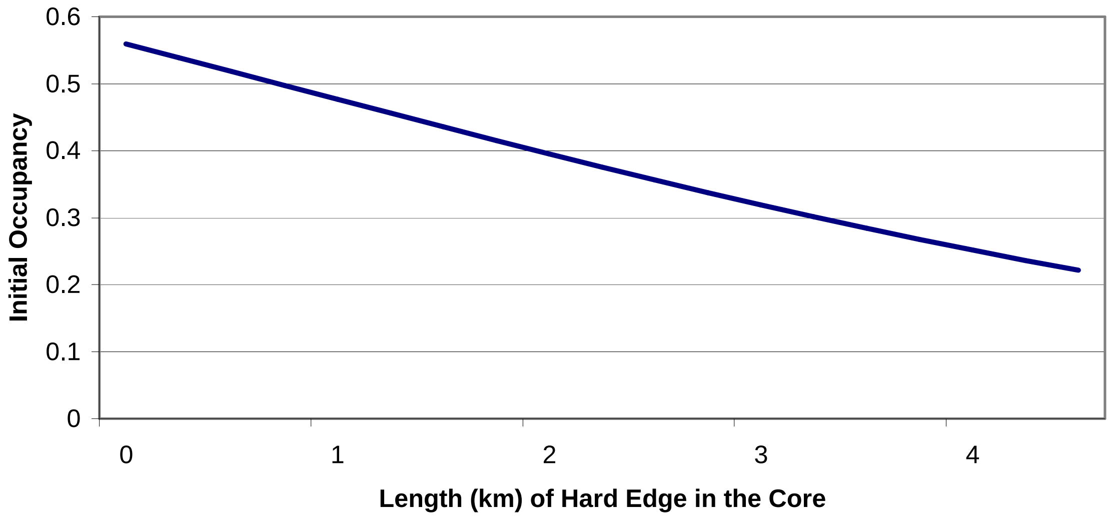

Figure 3.6. The effect of hard edge within the core on initial occupancy at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 – 2006. Estimates generated from model Ψ(RFLc + EDGEc) ε(BIS,TR=Q + T + lnUNSUITc + EDGEhr) γ(NRFLc + lnHIGHhr) p(.,.) using equation logit (Ψ) = 0.587 + 0.076(RFLc) – 0.332(EDGEc).

Extinction Probabilities

One model was competitive with the top extinction model ε(BIS,TR=Q + T + lnUNSUITc + EDGEhr) (Table 3.3, Appendix F), but this model was identical to the best model minus EDGEhr. The best extinction model indicated that extinction probabilities were greater at the Biscuit Fire (β = 5.58, 95% C.I. = 1.25 – 9.91) than the Quartz and Timbered Rock Fires, and increased in a linear fashion over time (β = 2.96, 95% C.I. = 0.97 – 4.94) at all study areas. Extinction probabilities increased in a curvilinear manner as the amount of unsuitable habitat in the core increased (β = 2.15, 95% C.I. = 0.25 – 4.05) (Figure 3.7). Furthermore, extinction probabilities were positively associated with the amount (km) of edge at a home range scale (β = 0.20, 95% C.I. = -0.01 – 0.41) (Figure 3.8).

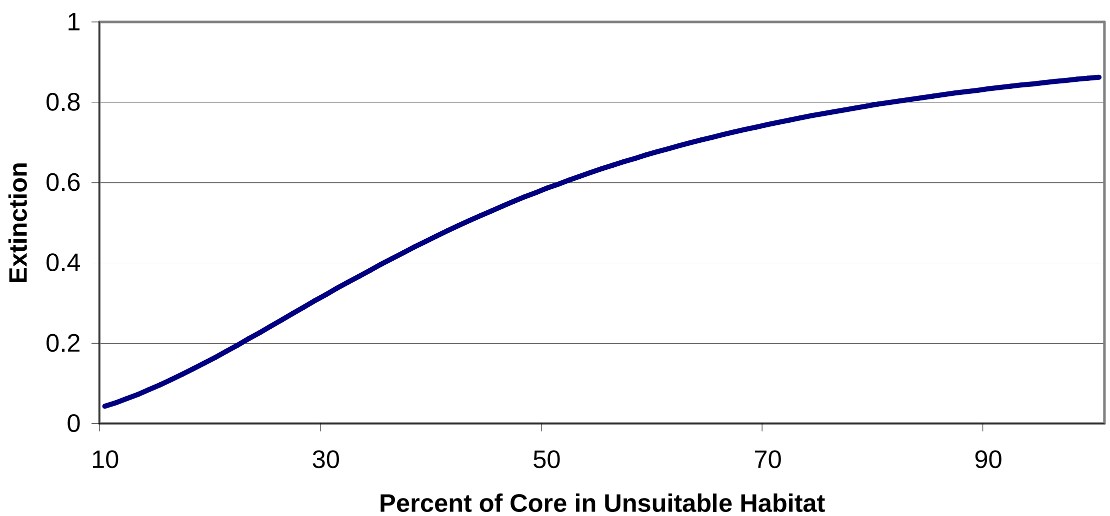

Figure 3.7. The effect of unsuitable habitat within the core area on extinction rates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 – 2006. Estimates generated from model Ψ(RFLc + EDGEc) ε(BIS,TR=Q + T + lnUNSUITc + EDGEhr) γ(NRFLc + lnHIGHhr) p(.,.) using equation logit (ε) = -22.249 + 5.579(AREA) + 2.956(T) + 2.148(lnUNSUITc) + 0.198(EDGEhr). AREA = 0.5, T = 1, and EDGEhr = 42.662, which are medians during interval 1.

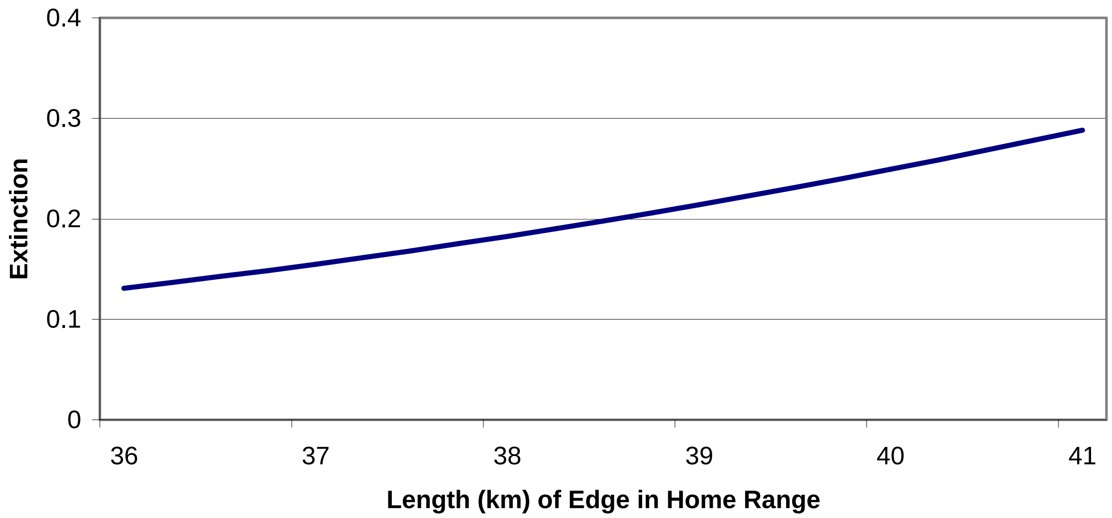

Figure 3.8. The effect of hard edge within the home range on extinction rates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 – 2006. Estimates generated from model Ψ(RFLc + EDGEc) ε(BIS,TR=Q + T + lnUNSUITc + EDGEhr) γ(NRFLc + lnHIGHhr) p(.,.) using equation logit (ε) = -22.249 + 5.579(AREA) + 2.956(T) + 2.148(lnUNSUITc) + 0.198(EDGEhr). AREA = 0.5, T = 1, and lnUNSUITc = 3.483, which are medians during interval 1.

Colonization Probabilities

Several models were competitive with the best colonization model γ(NRFLc + lnHIGHhr) (Table 3.3, Appendix G). Competing models were variations of the top model or included 1 additional parameter that had beta coefficients that broadly overlapped 0. Therefore, competing models were not considered further because the top model had a better fit. Colonization was positively associated with the amount of nesting, roosting and foraging habitat with low severity burn within the core (β = 0.08, 95% C.I. = 0.02 – 0.15) (Figure 3.9). In addition, colonization was positively related to the amount of high severity fire within the home range (β = 2.30, 95% C.I. = 0.21 – 4.39) (Figure 3.10). This may seem a spurious result, but colonization probabilities are dependent on a site being unoccupied in the previous time interval (MacKenzie et al.

2003). Therefore, a site that had a large amount of high severity fire was likely unoccupied (i.e. gone extinct) and was available for colonization.

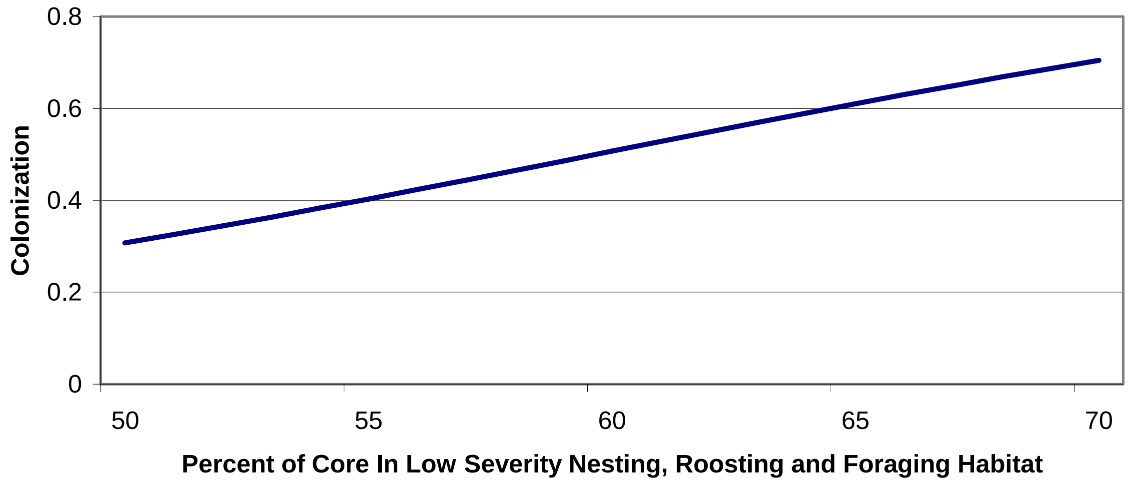

Figure 3.9. The effect of nesting, roosting and foraging habitat with a low severity burn within the core area on colonization rates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 – 2006. Estimates generated from model Ψ(RFLc + EDGEc) ε(BIS,TR=Q + T + lnUNSUITc + EDGEhr) γ(NRFLc + lnHIGHhr) p(.,.) using equation logit (γ) = -10.223 + 0.084(NRFLc) + 2.302(lnHIGHhr).

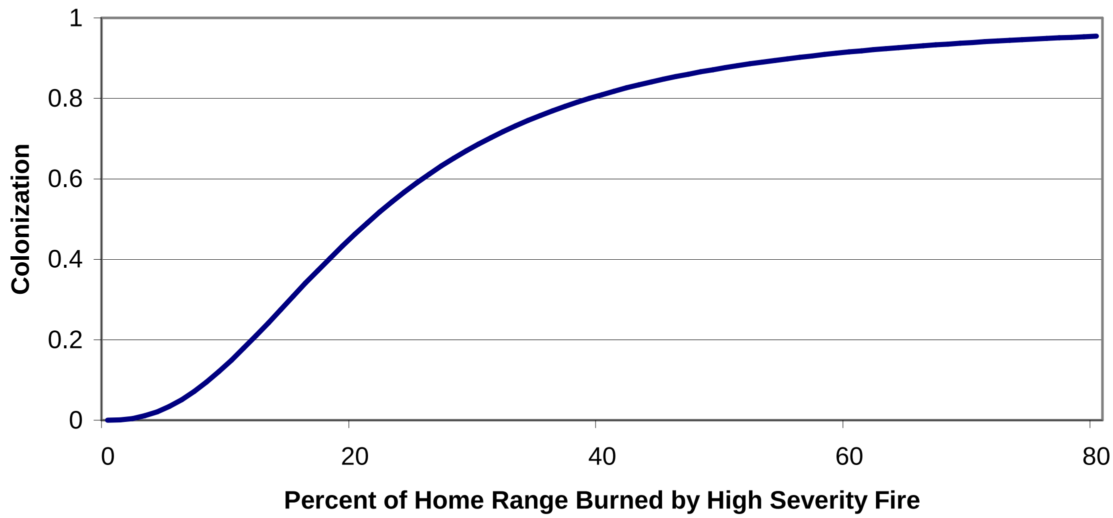

Figure 3.10. The effect of high severity fire within the home range on colonization rates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 – 2006. Estimates generated from model Ψ(RFLc + EDGEc) ε(BIS,TR=Q + T + lnUNSUITc + EDGEhr) γ(NRFLc + lnHIGHhr) p(.,.) using equation logit (γ) = -10.223 + 0.084(NRFLc) + 2.302(lnHIGHhr).

DISCUSSION

Comparison of the South Cascades to Timbered Rock

The Timbered Rock and South Cascades study areas had similar trends in occupancy rates prior to the Timbered Rock Fire. In contrast, extinction rates at Timbered Rock greatly increased following wildfire, which led to large declines in occupancy that were not observed in the South Cascades. This supported my prediction that occupancy rates in burned landscapes would decline when compared to unburned landscapes with similar habitat. The increased extinction rates observed following wildfire were likely related to decreased survival and increased emigration. Several spotted owls (2 pairs and 1 individual) emigrated to the nearest unoccupied territory outside the fire 1 to 2 years after the fire. Adult dispersal is relatively rare in spotted owls (Forsman et al. 2002, Zimmerman et al. 2007), so this relatively high level of dispersal observed following fire may suggest that there was insufficient habitat remaining at these territories following wildfire. Furthermore, barred owls (*Strix varia*) likely had little impact on the declines post-fire occupancy at Timbered Rock because no barred owls were detected in 4 years of post-fire demographic surveys at the Timbered Rock Fire.

Owls that remained within the fire had decreased survival (see Chapter 4), which likely contributed to elevated extinction rates following wildfire. Wildfire reduced the amount of older forest and increased the amount of unsuitable habitat through mortality of overstory trees. Spotted owl survival rates were positively associated with greater amounts of older forest in other studies (Franklin et al. 2000, Olson et al. 2004, Blakesley et al. 2005, Dugger et al. 2005), so it is not surprising that wildfire may negatively impact spotted owl survival and subsequently occupancy rates in this study.

Several owl territories occupied prior to the Timbered Rock Fire had large amounts of suitable habitat consumed by stand-replacing wildfire and subsequent salvage logging. These owl territories were unoccupied following wildfire and will likely not serve as owl territories until mature and older forests are restored. In addition to increasing post-fire extinction rates the year immediately following wildfire, it is unlikely that these sites will be colonized for many years due to large amounts of unsuitable habitat. Consequently, the number of owl territories with sufficient habitat declined following wildfire, which reduced the total owl population that was supported in the post-fire landscape.

Post-fire extinction rates at Timbered Rock may have been exacerbated by the checkerboard land ownership pattern of private and BLM lands (Richardson 1980). Following wildfire much of the private land was salvage logged, which created large amounts of unsuitable habitat and habitat fragmentation throughout the landscape. High levels of habitat fragmentation are hypothesized to negatively influence animal populations (Wilcox and Murphy 1984, Wilcove et al. 1986), although the effects of landscape level fragmentation on spotted owls is not well studied (Franklin and Gutiérrez 2002). Large amounts of unsuitable habitat were negatively associated with spotted owl occupancy (Blakesley et al. 2005) and this may be the case for the Timbered Rock Fire in my study.

Influence of Wildfire on Post-Fire Occupancy

Initial Occupancy

Initial occupancy rates were similar for the Biscuit, Quartz and Timbered Rock Fires but were positively associated with increased amounts of roosting and foraging habitat with low severity burn. Previous research suggested that owl territories that are not entirely comprised of older forest had increased survival and reproduction (Franklin et al. 2000, Olson et al. 2004) and it is apparent that owl territories in this study that had some roosting and foraging habitat with low severity burn within the core area had higher initial occupancy rates. However, initial occupancy rates were negatively impacted by the amount of edge within the core area in this study. Edge habitat may have been correlated with the amount of unsuitable habitat, and I suspect that increases in edge may indicate increased amounts of unsuitable habitat at some territories. Blakesley et al. (2005) found that spotted owl occupancy was negatively associated with increased unsuitable habitat; therefore, I hypothesize that edge may indicated decreased amounts of suitable habitat which negatively influenced initial occupancy in my study. Furthermore, if there are insufficient amounts of interior forest within the core, owls likely can not persist on the site (Franklin et al. 2000). Therefore, edge in this study may have indicated that the area of interior forest was reduced by wildfire and salvage logging, and these factors negatively influenced initial occupancy rates.

Extinction

I predicted that post-fire occupancy would decline because of elevated extinction rates due to habitat loss related to high severity fire and salvage logging. My results supported this prediction because elevated extinction rates were associated with increased amounts of unsuitable habitat (the combination of high severity fire, salvage logging and early seral forests prior to fire). As the amount of unsuitable habitat increased within the core area, extinction rates increased in a curvilinear manner until a high extinction threshold was reached at large amounts of unsuitable habitat. This result was supported by the literature because spotted owls are associated with late-successional forests (Forsman et al. 1984, Thomas et al. 1990), and spotted owl nest sites typically have greater amounts of older forests than the surrounding landscape (Ripple et al. 1991, 1997, Lemkuhl and Raphael 1993, Meyer et al. 1998, Swindle et al. 1999). Therefore, territories with large amounts of unsuitable habitat will likely not support spotted owls in post-fire landscapes. Furthermore, spotted owl survival was positively correlated with older forest in other studies (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005). Spotted owl site extinction rates are likely driven by survival because spotted owls have high site fidelity (Forsman et al. 1984, 2002, Zimmerman et al. 2007). Consequently, as the amount of unsuitable habitat increased due to previous land management activities, high severity fire, or salvage logging, survival rates likely declined and led to elevated extinction rates and subsequently declines in occupancy.

Extinction rates after fire also increased as the amount of edge increased within the home range scale. In many spotted owl territories the amount of edge may be correlated with the amount of unsuitable habitat, which was associated decreased survival and occupancy of spotted owls (Blakesley et al. 2005) and was positively correlated with extinction rates in this study. Furthermore, edge habitat may be indicative of decreased patch sizes and increased fragmentation. My results indicate that pre-fire harvest and post-fire salvage coupled with high severity fire reduced the amount of suitable owl habitat, increased site extinction rates, and subsequently created declines in occupancy. In addition, barred owls likely had little impact on site extinction rates because only 1 barred owl was detected in 4 years of demographic surveys at the 3 fires.

Colonization

Colonization rates in my study were constant over time after fire and between study areas but were positively associated with increased amounts of nesting, roosting and foraging habitat with low severity burn in the core area. This result was expected because spotted owls are dependent upon older forests (Forman et al. 1984, Thomas et al. 1990), and spotted owl nesting centers have greater amounts of late-successional forests than the surrounding landscapes (Ripple et al. 1991, 1997, Lemkuhl and Raphael 1993, Swindle et al. 1999). Therefore, owl territories that had greater amounts of late-successional forest following wildfire had the highest probability of being colonized. In addition, colonization rates in my study were positively associated with increased amounts of high severity fire in the home range. High severity wildfire created unsuitable spotted owl habitat, which increased site extinction rates. In occupancy modeling, colonization rates are dependent upon a site being unoccupied the previous year(s) (MacKenzie 2003). Because sites that have large amounts of high severity fire were likely unoccupied (i.e. gone extinct) they were available for colonization.

Ultimately, occupancy rates of territorial species with high site fidelity and adult survival rates such as spotted owls will be impacted the most by extinction rates. Therefore, it is apparent that pre-fire timber harvest, high severity fire, and post-fire timber harvest have detrimental impacts on site occupancy by spotted owls by increasing the amount of unsuitable habitat, which increased extinction rates. These events may have caused decreased survival rates of spotted owls through the reduction of suitable habitat (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005) and negatively influenced spotted owl populations following wildfire.

The results from my research suggest that the owl populations monitored during this research project declined due to the apparent declines in post-fire occupancy rates created by high extinction rates and low colonization rates. For these populations to remain stable or increase, colonization rates must increase through increased reproductive output or immigration, extinction rates need to decline, or a combination of the two factors must occur. Furthermore, until late-successional forest conditions are restored at several territories consumed by stand-replacing fires, the total number of owls that can be supported by the Biscuit, Quartz and Timbered Rock Fires was reduced.

It is apparent that wildfire led to declines in post-fire occupancy of spotted owls, it is likely that wildfire may be essential to the long-term conservation of spotted owls in dry forest ecosystems where wildfire is common. Low and moderate severity burns likely reduce the risk of stand-replacing wildfire in the future, but are likely detrimental to spotted owl site occupancy at least in the short-term. Active fire suppression is still practiced throughout much of the western United States, therefore natural wildfire is likely not an option to reduce fire risk in spotted owl habitat. Therefore, land managers are faced with the difficult task of trying to implement prescribed burning or mechanical thinning treatments in spotted owl habitat. The management of dry forest ecosystems is a contentious issue (Bestcha et al. 2004, Noss et al. 2006) and it will be difficult to reach consensus among biologists, researchers and land managers on the best methods to reduce the risk of stand-replacing wildfire while limiting detrimental impacts to spotted owls, their habitat and prey. Furthermore, the implementation of fire reduction techniques across a large enough scale to be effective may be limited by monetary resources.

CHAPTER 4

SURVIVAL AND PRODUCTIVITY OF NORTHERN SPOTTED OWLS IN POST-FIRE LANDSCAPES OF SOUTHWESTERN OREGON

Darren A. Clark

INTRODUCTION

The likelihood of stand replacing wildfire may have increased in the dry forest provinces of the Pacific Northwest due to active fire suppression during the latter half of the 20th century (Agee 1993). From 1994 – 2006, wildfire surpassed timber harvest as the leading cause of habitat loss on lands administered by the Federal Government within the range of the northern spotted owl (*Strix occidentalis caurina*, hereafter spotted owl) (Davis and Lint 2005). However, the impacts of wildfire on spotted owl survival and reproduction are not well studied. Reproductive rates of Mexican spotted owls (*Strix occidentalis lucida*) in burned landscapes was slightly less than in unburned landscapes (Jenness et al. 2004) and the subspecies still reproduced following low intensity prescribed fire (Sheppard and Farnsworth 1997). Furthermore, Bond et al. (2002) found minimal short-term impacts (< 1 year) on survival and reproduction of northern, Mexican and California spotted owls (*Strix occidentalis occidentalis*).

While the limited research in burned landscapes suggests minimal impacts of wildfire on survival and reproduction of spotted owls, research in unburned landscapes indicates that wildfire may negatively impact survival and reproduction of spotted owls through the destruction of suitable habitat. Spotted owl survival tends to be positively associated with greater amounts of late-successional forest within the territory (Franklin et al. 2000, Olson et al. 2004, Blakesley et al. 2005, Dugger et al. 2005). Furthermore, survival and reproduction of spotted owls is often negatively associated with increased amounts of unsuitable habitat (Bart and Forsman 1992, Bart 1995, Ripple et al. 1997, Blakesley et al. 2005, Dugger et al. 2005). Wildfire and subsequent salvage logging decreased the amount of suitable habitat and increased the amount of unsuitable habitat and may negatively impact spotted owl survival and reproduction. Conversely, recent work has suggested a potential benefit of forest edge habitat, demonstrated by increased productivity and survival at owl territories that are not entirely comprised of late-successional forests (Franklin et al. 2000, Olson et al. 2004). Their results exemplify the spotted owl's evolutionary adaptations to respond to forest heterogeneity created by natural disturbances such as wildfire.

Several spotted owl populations throughout the Pacific Northwest continue to decline despite the lack of timber harvest on federally administered lands (Anthony et al. 2006). Losses of spotted owl habitat to wildfire in dry forest provinces is exceeding previous predictions (Davis and Lint 2005), and the sustainability of owl populations in dry forest provinces is being questioned due to the increased risk of habitat loss to wildfire (Spies et al. 2006). Therefore, it is essential to develop an understanding of the impacts of wildfire on spotted owl survival and reproduction to incorporate these impacts in management plans and ensure the long term conservation of the species.

The purpose of the study was to determine the short-term impacts of wildfire on spotted owl survival and reproductive output. I predicted that (1) spotted owl productivity would decline following wildfire, (2) productivity would be higher in unburned landscapes compared to burned landscapes, (3) survival rates of owls living in burned landscapes would be lower than those living in unburned landscapes, and (4) survival rates would decrease as the amount of high severity fire and salvage logging increased within individual territories.

METHODS

Productivity

Demographic surveys were conducted annually between 1 March and 31 August to determine the number of young fledged at occupied territories following established protocols (Lint et al. 1999). Surveys were conducted at 22 territories within Timbered Rock prior to wildfire (1992 – 2002) and following wildfire (2003 – 2006). Nine territories were surveyed at the Biscuit and Quartz fires from 2003 – 2006. In addition, surveys were conducted at the South Cascades Demography Area (South Cascades) from 1992 – 2006 by the OCWRU as part of the range-wide monitoring program for spotted owls (Lint et al. 1999, Anthony et al. 2006). This information was used as a comparison of productivity rates between burned and unburned landscapes.

Owl territories that were occupied by a pair of spotted owls were assigned a value between 0 – 3, which indicated the number of young fledged by that pair. If an owl territory was unoccupied or occupied by a single owl, no data were entered for that site because productivity was calculated as the number of young fledged per pair of spotted owls, not per territory. Because count data are not normally distributed, I used a Kruskal-Wallis nonparametric ANOVA to test for differences in productivity among groups (Ramsey and Schafer 2002:136). If the null hypothesis was rejected, I conducted multiple Wilcoxon rank-sum tests to investigate specific questions of interest (Ramsey and Schafer 2002:90). I adjusted the alpha level to determine significance from 0.05 to 0.01 to account for multiple comparisons using the Wilcoxon rank-sum test.

Comparison of the South Cascades and Timbered Rock

I tested for differences in productivity among 4 groups that included; (1) pre-fire years at Timbered Rock (1992 – 2002), (2) post-fire years at Timbered Rock (2003 – 2006), (3) pre-Timbered Rock Fire years at the South Cascades (1992 – 2002), and (4) post-Timbered Rock Fire years at the South Cascades (2003 – 2006). In addition to testing for differences among groups, I conducted paired comparisons to investigate 4 specific questions. The first comparison investigated changes in productivity over time unrelated to fire at the South Cascades during the 1992 – 2002 and 2003 – 2006 sampling periods. The second comparison investigated differences in pre and post-fire productivity at Timbered Rock to determine if productivity declined post-fire. I also investigated differences in productivity between burned and unburned landscapes by comparing post-fire productivity at Timbered Rock to the South Cascades from 2003 – 2006. Finally, I investigated differences in productivity under unburned conditions among study areas by comparing pre-fire productivity at Timbered Rock to the South Cascades from 1992 - 2002.

Comparison of Burned and Unburned Landscapes

I tested for differences in productivity among 3 burned landscapes at the Biscuit, Quartz and Timbered Rock Fires and 1 unburned landscape at the South Cascades to investigate if productivity was different at any of the study areas from 2003 - 2006. Paired comparisons of each possible group combination were conducted to determine if individual study areas had different productivity than the others.

Radio-telemetry Monitoring and Survival

Twenty-four spotted owls were radio-marked at the Timbered Rock and Quartz Fires and surrounding areas and included in the analysis of survival (Appendix H). From September 2004 – August 2006 the fate of individual owls was recorded approximately every other day by noting if the transmitter signal indicated the owl was alive or dead. If transmitters switched to mortality mode, field crews would hike in and locate the carcass/remains of the owl and determine cause of death as soon as possible. In the event that owls could not be located from the ground, aerial searches were conducted using fixed-wing aircraft. If the individual was not located during aerial searches, it was assumed the transmitter failed or the owl emigrated from the study area, in which case the individual was censored from the data set.

I estimated survival rates in program MARK using known fate models for radio-marked individuals (White and Burnham 1999). Program MARK used a modified Kaplan-Meier (1958) estimator that allowed for staggered data entry and censoring of individuals (Pollock et al. 1989) to estimate survival rates. This allowed owls to be entered into the data set during the first month they were monitored the entire month (not the month they were captured, unless capture was within the first week of the month). If the fate of an individual was not known the first and last week of the month they were censored for that month. In addition, owls were censored following transmitter failure until they were recaptured and fitted with a new transmitter.

Program MARK used maximum likelihood estimation to optimize model parameters and to fit models to the data (White and Burnham 1999). Model selection was conducted using Akaike's Information Criterion, corrected for small sample sizes

(AIC_c) and Akaike weights (Burnham and Anderson 2002). The top model was assumed to be the model with the lowest AIC_c value, and models within 2 ΔAIC_c were considered competing and given consideration. Models with the lowest AIC_c were used to interpret results and survival estimates are reported from the best model.

Survival was estimated at a monthly interval, with data entered as either the animal survived, died, or was censored during the month. I investigated models that incorporated all possible time effects including constant monthly survival (.), time-specific models (t), and linear (T), quadratic (TT), or curvilinear (lnT) trends over time. In addition, I tested models that incorporated differences between 6 groups; females and males inside the fire (groups 1 and 2), females and males displaced by fire (groups 3 and 4), and females and males outside the fire (groups 5 and 6). I hypothesized that owls inside the fire would have decreased survival due to habitat loss and that owls displaced by fire (emigrated out of the fire boundary) would have decreased survival due to energetic stresses associated with residing inside the fire and subsequent emigration. Combinations of group and time effects were considered where appropriate. I conducted 2 separate analyses; one that estimated annual survival and another that estimated survival over the entire 19 month sampling period that incorporated habitat specific covariates. Annual survival was estimated during the first 12 months of the study (1 October 2004 – 30 September 2005) because this interval included the most radio-marked individuals (n = 23). During this time, 5 owls died, and 1 owl was censored for 2 months due to transmitter failure.

Survival also was estimated for 19 months from 1 October 2004 – 30 April 2006 on a sample of 24 owls. During this period, 8 owls died, 1 owl was censored for 2 months due to transmitter failure, and 1 owl was censored due to unknown fate (mortality censor triggered but remains and transmitter were never found). In addition to modeling time and area effects, I also included habitat covariates that influence survival. The covariates I considered were the same as those I used in the analysis of occupancy (see Chapter 3, Table 3.1). Covariate values were calculated in ArcGIS 9.1 as the proportion of each habitat class within the boundaries of individual 95% fixed kernel home ranges estimated by program KernelHR (Seaman et al. 1998).

RESULTS

Productivity

Comparison of the South Cascades to Timbered Rock

The mean number of young fledged per owl pair per year varied over time and between study areas (Figure 4.1). The mean number of young fledged per pair per year at the South Cascades was 0.68 (95% C.I. = 0.61 – 0.75) in 1992 – 2002 and 0.63 (95% C.I. = 0.52 – 0.74) in 2003 – 2006. Owl pairs at Timbered Rock averaged 0.42 young per year (95% C.I. = 0.28 – 0.56) prior to fire and 0.20 young per year (95% C.I. = -0.05 – 0.44) following fire. There was substantial evidence that at least 1 of the study areas had different productivity than the others (χ^2 = 12.06, df = 3, p = 0.01).

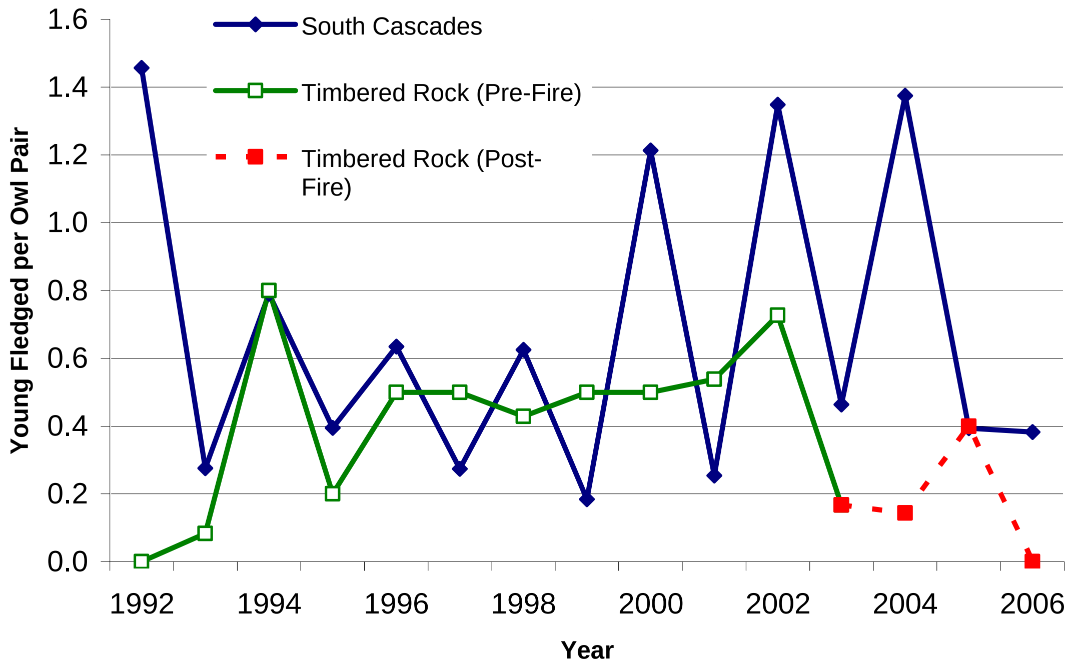

Figure 4.1. The mean number of young fledged per pair of owls each year at the Timbered Rock and South Cascades Study Areas in southwestern Oregon from 1992 – 2006.

Productivity at the South Cascades was significantly greater than Timbered Rock during the pre-fire sampling period from 1992 – 2002 ($Z = 2.67$, $p = 0.01$). There was suggestive evidence that the South Cascades had greater productivity than Timbered Rock during the post-fire sampling period from 2003 – 2006 ($Z = 2.18$, $p = 0.03$) and I likely lacked precision to detect a significant difference at the lower alpha level. Pre- and post-fire productivity at Timbered Rock did not differ ($Z = 1.21$, $p = 0.23$). There also was no observed difference in productivity at the South Cascades between 1992 – 2002 and 2003 – 2006 ($Z = 0.57$, $p = 0.57$). These results indicated that there was a significant difference in productivity between Timbered Rock and the South Cascades over all years of sampling and productivity has been historically lower at Timbered Rock regardless of fire effects. Furthermore, post-fire productivity at the Timbered Rock Fire was not significantly different than pre-fire, which may indicate that productivity was not influenced by wildfire, but I may have lacked precision to obtain significant differences.

Comparison of Burned and Unburned Landscapes

From 2003 – 2006 the mean annual number of young fledged per owl pair varied by area and year (Figure 4.2). Productivity was greatest at the Biscuit Fire ($\bar{x}$ = 0.83, 95% C.I.. = 0.24 – 1.43), followed by the South Cascades ($\bar{x}$ = 0.63, 95% C.I. = 0.52 – 0.74), the Quartz Fire ($\bar{x}$ = 0.50, 95% C.I. = 0.20 – 0.80), and the Timbered Rock Fire ($\bar{x}$ = 0.20, 95% C.I. = -0.04 – 0.44). There was little evidence to suggest that at least 1 of the study areas had different productivity than the others (χ^2 = 5.76, df = 3, p = 0.12). These results indicated that there were no statistical differences in productivity between burned and unburned landscapes from 2003 – 2006, although I likely lacked precision to obtain a significant difference.

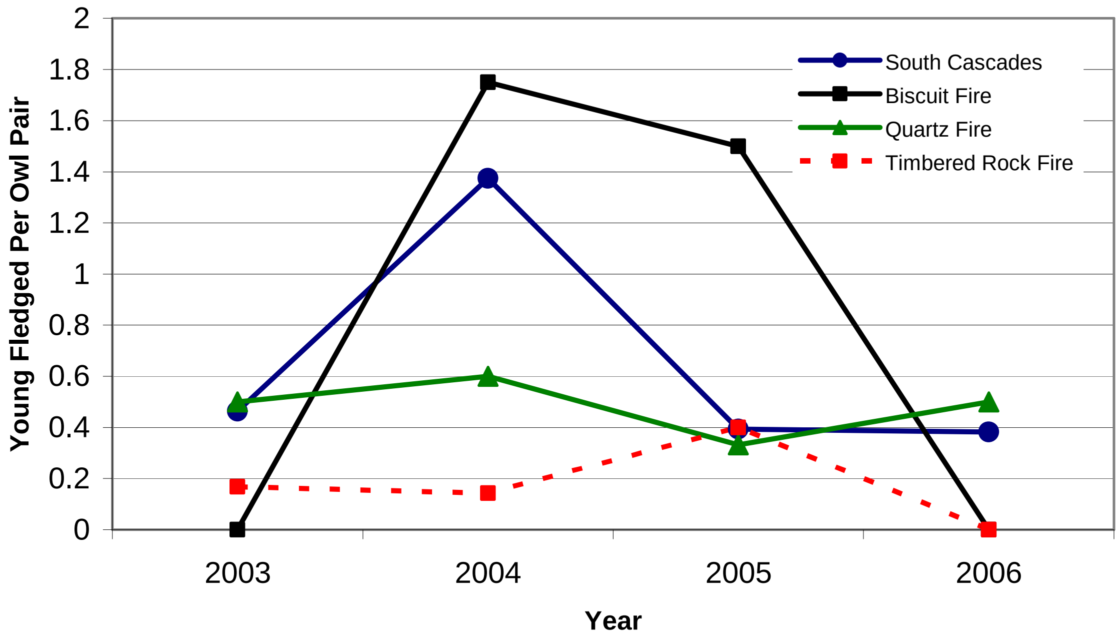

Figure 4.2. The mean number of young fledged per pair of owls each year at the Biscuit, Quartz, Timbered Rock and South Cascades Study Areas in southwestern Oregon from 2003 – 2006.

Survival

Owl Mortalities

During the study, 8 of 24 owls (33%) died and the fate of 1 owl was never determined. Six owl carcasses were submitted for necropsy at the Oregon State University, College of Veterinary Medicine, Veterinary Diagnostic Lab (VDL) in Corvallis, Oregon, and all 6 owls were severely emaciated and likely died of starvation (Table 4.1). The VDL found no injuries caused by the radio-transmitter package and all owls tested negative for West Nile Virus. Two owls were not submitted for necropsy because limited remains (scattered feathers and the transmitter package) were present at the mortality scenes, which indicated predation by a great horned owl (*Bubo virginianus*) or northern goshawk (*Accipiter gentilis*).

Table 4.1. Date and cause of death of 8 radio-tagged northern spotted owls monitored during radio-telemetry research at the Quartz and Timbered Rock Fires in southwestern Oregon from September 2004 - August 2006.

Owl	Mortality Date	Cause of Death
Upper Timber Female	1/18/2005	Emaciation
Upper Timber Male	5/7/2005	Emaciation/Parasitism
Oliver Springs Female	5/16/2005	Emaciation/Parasitism
Miller Mountain Male	7/12/2005	Predation
Yale Creek Male	7/13/2005	Emaciation/Broken Leg
Hawk Creek Male	1/4/2006	Emaciation
South Boundary Male	2/13/2006	Predation
Glade Creek Male	4/8/2006	Emaciation

Annual Survival

There was no evidence of overdispersion in the annual survival data set because $\hat{c}$ was <1 for the global model [S(Group * t)]. The best model for annual survival rates of spotted owls indicated that owls inside or displaced by fire had similar survival rates but owls outside the fire had different survival [S(Group 1=2=3=4 , 5=6)] (Table 4.2). Two models were competitive with the best model including [S(.)] and [S(Area)]. The Akaike weight of the best model was less than 1.5 times that of competing models. The best model indicated that monthly survival rates were constant and that owls outside the fire had higher monthly survival rates ($\hat{s}$ = 1.00, SE = 0.00) than owls that were inside or displaced by the fire ($\hat{s}$ = 0.96, SE = 0.02). Model S(.) suggested constant monthly survival rates with no differences between groups. Model S(Area) suggested that monthly survival rates were constant but owls outside the fire had the highest survival, owls inside the fire had intermediate levels of survival and owls displaced by fire had the lowest survival. There was little evidence that annual survival rates of spotted owls were influenced by sex or time, because models that incorporated these effects were not competitive.

Table 4.2. Model selection results for known fate models that estimated annual survival of northern spotted owls (n = 24) at the Timbered Rock and Quartz Fires from October, 2004 - September 2005.

Model[a]	AICc	ΔAICc	AICc Weights	Model Likelihood	K	Deviance
{S(Group1=2=3=4,5=6)}	46.839	0.000	0.248	1.000	2	21.270
{S(.)}	47.604	0.765	0.169	0.682	1	24.081
{S(Area)}	48.419	1.579	0.113	0.454	3	20.780
{S(lnT)}	49.182	2.342	0.077	0.310	2	23.612
{S(T)}	49.481	2.642	0.066	0.267	2	23.911
{S(Sex)}	49.559	2.719	0.064	0.257	2	23.989
{S(Group1=2,3=4=5=6)}	49.620	2.780	0.062	0.249	2	24.050
{S(Area+lnT)}	49.891	3.052	0.054	0.217	4	20.159
{S(TT)}	50.124	3.285	0.048	0.194	3	22.485
{S(Group1=2=3=4,5=6*lnT)}	50.170	3.330	0.047	0.189	4	20.437
{S(Area+T)}	50.244	3.405	0.045	0.182	4	20.512
{S(Group)}	54.552	7.712	0.005	0.021	6	20.559
{S(t)}	58.399	11.560	0.001	0.003	12	11.007
{S(Sex*t)}	84.191	37.351	0.000	0.000	24	6.846
{S(Group1=2=3=4,5=6*t)}	85.386	38.546	0.000	0.000	24	8.041
{S(Group1=2,3=4=5=6*t)}	87.856	41.016	0.000	0.000	24	10.512
{S(Area*t)}	119.711	72.871	0.000	0.000	36	7.316
{S(Group*t)}	265.615	218.776	0.000	0.000	72	0.000

[a] Variable definitions: . = constant survival, t = survival varies by month, T = linear time trend, lnT = curvilinear time trend, TT = quadradic time trend, Group = indicator variables for 6 groups, 1 and 2 - females and males inside the fire, 3 and 4 - females and males displaced by the fire, 5 and 6 - females and males outside the fire, Area = indicator variables for 3 groups - inside fire, displaced by fire and outside fire, Sex = indicator variable distinguishing males and females.

Model [S(Group 1=2=3=4,5=6)] indicated that owls within or displaced by fire had a monthly survival rate of 0.96 (95% C.I. = 0.91 – 0.98) and owls outside the fire had a monthly survival rate of 1.00 (95% C.I. = 1.00 – 1.00), which resulted in an annual survival rate of 0.64 (95% C.I. = 0.37 – 0.84) for owls within or displaced by fire and 1.00 (95% C.I. = 1.00 – 1.00) for owls outside the fire. This likely indicated that owls unaffected by wildfire had higher survival rates than owls affected by fire, but my sample of owls outside the fire was small (*n* = 6). The estimate of annual survival for owls affected by fire had a coefficient of variation of 20.3%, and the estimate for owls outside the fire had a coefficient of variation of 0.0%. The probability of any owl surviving the first 12 months of the study under model S(.) was 0.71 (95% C.I. = 0.47 – 0.87). Finally, model S(Area) indicated that owls inside the fire, displaced by fire, and outside the fire had annual survival rates of 0.69 (95% C.I. = 0.37 – 0.90), 0.49 (95% C.I. = 0.12 – 0.87) and 1.00 (95% C.I. = 1.00 – 1.00), respectively, but these estimates lacked precision due to the small sample size.

Study Long Survival

The best model [S(Group 1=2=3=4,5=6 + T)] that described survival rates from September 2004 – April 2006 indicated that there was a linear trend in monthly survival rates, and owls outside the fire had different survival rates than owls inside or displaced by fire (Table 4.3). There were 2 competing models and the first competing model was identical to the top model, except that it included constant monthly survival rates. This model was not considered further because the linear trend in monthly survival rates was significant and the top model had a better fit to the data. The second competing model was [S(Area + T)] but the ΔAICc was almost 2 and the weight of the top model was ~3 times that of this model, which provided little support for this model. Overdispersion was not present in this data set because $\hat{c}$ was < 1 for the global model [S(Group * t)].

Table 4.3. Model selection results for 19 month known fate models that estimated survival of northern spotted owls (*n* = 24) at the Timbered Rock and Quartz Fires from October, 2004 - April 2006.

Model[a]	AICc	ΔAICc	Akaike Weight	Model Likelihood	K	Deviance
{S(Group1=2=3=4,5=6+T)}	68.531	0.000	0.331	1.000	3	34.339
{S(Group1=2=3=4,5=6)}	69.230	0.698	0.234	0.705	2	37.087
{S(Area+T)}	70.481	1.950	0.125	0.377	4	34.223
{S(Area)}	70.944	2.413	0.099	0.299	3	36.752
{S(.)}	72.568	4.036	0.044	0.133	1	42.458
{S(T)}	72.916	4.385	0.037	0.112	2	40.774
{S(Sex)}	73.059	4.528	0.034	0.104	2	40.917
{S(lnT)}	73.138	4.607	0.033	0.100	2	40.996
{S(Group)}	73.705	5.174	0.025	0.075	5	35.362
{S(Group1=2,3=4=5=6)}	74.204	5.673	0.019	0.059	2	42.062
{S(TT)}	74.331	5.800	0.018	0.055	3	40.139
{S(Group1=2=3=4,5=6+t)}	83.687	15.155	0.000	0.001	20	11.860
{S(Area+t)}	85.614	17.083	0.000	0.000	21	11.396
{S(t)}	88.951	20.420	0.000	0.000	19	19.495
{S(Sex+t)}	89.604	21.073	0.000	0.000	20	17.778
{S(Group1=2,3=4=5=6+t)}	90.712	22.181	0.000	0.000	20	18.886
{S(Group+t)}	92.433	23.902	0.000	0.000	24	10.911
{S(Sex*t)}	128.169	59.638	0.000	0.000	38	9.757
{S(Group1=2=3=4,5=6*t)}	130.272	61.741	0.000	0.000	38	11.860
{S(Group1=2,3=4=5=6*t)}	131.834	63.303	0.000	0.000	38	13.423
{S(Area*t)}	185.259	116.727	0.000	0.000	57	7.995
{(Global)}	456.246	387.714	0.000	0.000	114	0.000

[a] Variable definitions: . = constant survival, t = survival varies by month, T = linear time trend, lnT = curvilinear time trend, TT = quadradic time trend, Group = indicator variables for 6 groups, 1 and 2 - females and males inside the fire, 3 and 4 - females and males displaced by the fire, 5 and 6 - females and males outside the fire, Area = indicator variables for 3 groups - inside fire, displaced by fire and outside fire, Sex = indicator variable distinguishing males and females.

In addition to modeling group and time effects, I investigated the effects of habitat covariates on owl survival. After an initial investigation, I found that the effect of habitat covariates was rarely significant because the 95% C.I.'s of the Beta coefficients widely overlapped 0. Therefore, I concluded that I lacked sufficient data (individual owls) to account for variability in survival due to habitat features within home ranges. The model that best described survival rates over the entire study indicated that owls that were displaced or within the fire had lower monthly survival rates than owls outside the fire.

Furthermore, monthly survival rates for owls inside or displaced by the fire declined in a linear manner during the course of the study (β = -0.14, 95% C.I. = -0.30 – 0.03), and the effect was important as the confidence interval of the Beta coefficient narrowly overlapped 0. The probability of owls within or displaced by fire surviving the entire 19 month sampling study period was 0.33 (95% C.I. = 0.12 – 0.64), while owls outside the fire had a probability of 1.00 (95% C.I. = 1.00 – 1.00) (Figure 4.3). The estimate of survival for owls inside or displaced by fire was imprecise with a coefficient of variation of 43.0%.

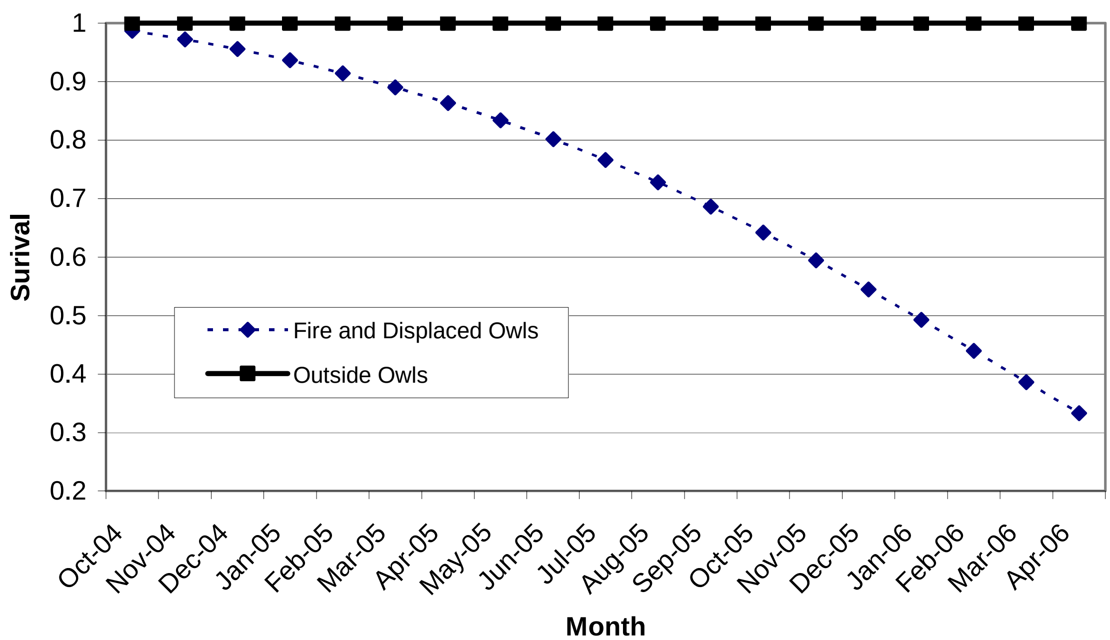

Figure 4.3. Compounded monthly survival estimates describing differences in study long survival rates (October 2004 – April 2006) between spotted owls displaced by or inside the fire and owls outside the fire, at the Timbered Rock and Quartz Fires and their surrounding areas in southwestern Oregon.

DISCUSSION

Productivity

Previous research suggested that spotted owl reproduction was positively related to the amount of older forests (Bart and Forsman 1992, Ripple et al. 1997, Dugger et al. 2005) and negatively related to the amount of unsuitable habitat (Blakesley et al. 2005) within the territory. Wildfire and subsequent salvage logging increased the amount of unsuitable habitat and decreased the amount of older forest throughout the Biscuit, Quartz and Timbered Rock Fires. Consequently, I predicted this would cause declines in productivity when compared to productivity in unburned landscapes, but this was not the case in my study. My results suggested that wildfire likely had little impact on productivity, which was similar to the results of Jenness et al. (2004) where productivity rates of Mexican spotted owls in burned landscapes were marginally less than unburned landscapes. Furthermore, reproductive rates of spotted owls 1 year following wildfire did not appear to be different than pre-fire rates in northern California (Bond et al. 2002).

In general, my results suggest that as long as a territory is capable of supporting a pair of spotted owls following wildfire, owl pairs in burned landscapes will produce young at a similar rate as unburned landscapes. Furthermore, barred owls (*Strix varia*) likely had minimal impacts on post-fire productivity in my study because only 1 barred owl was detected in 4 years of demographic surveys at the 3 fires. It may be the case that I lacked sufficient data to estimate a significant difference in mean productivity of owls in burned and unburned landscapes. Further studies with larger sample sizes over a longer time frame are needed to determine if significant differences exist between groups. Therefore, caution should be taken when applying my results to management plans that suggest wildfire has little impact on spotted owl productivity.

Perhaps the issue of greater concern is not the mean number of young fledged per owl pair per year, but rather total reproductive output following wildfire. Post-fire pair occupancy rates declined following wildfire (see Chapter 3), which decreased the total number of pairs available to produce young in post-fire landscapes. Therefore, wildfire negatively impacted reproductive output by decreasing the owl population, which decreased the total number of young fledged in the study area following fire. While owl pairs that persist in burned landscapes are likely still capable of producing young at a similar rate to owls in unburned landscapes, the total number of young fledged in post-fire landscapes is reduced due to apparent declines in post-fire occupancy. Therefore, reproductive output of the post-fire owl population is reduced when compared to the pre-fire owl population.

In contrast to my initial prediction, there was not a significant decline in productivity following the Timbered Rock Fire, but I likely lacked the precision to estimate a significant difference. Productivity was historically lower at Timbered Rock when compared to the South Cascades prior to wildfire and was also lower during post-fire sampling periods. This likely suggested that wildfire had little impact of productivity rates in burned landscapes, but definitive conclusions likely can not be made until additional studies with larger sample sizes are conducted. I was unable to determine if productivity declined following the Biscuit and Quartz Fires because I did not have pre-fire productivity data to compare to post-fire data. Furthermore, I lacked sufficient data (spotted owl pairs) to examine the effects of wildfire and habitat on territory specific reproductive output. Therefore, I was unable to draw direct conclusions in regards to the effects of wildfire and subsequent salvage on reproductive output at individual owl territories. Future research on the effects of wildfire on territory specific reproductive output are needed to clarify the impacts of different fire severities and salvage logging on spotted owl productivity.

Survival

In support of my initial prediction, annual survival rates of spotted owls displaced by wildfire or living inside fire boundaries (0.64, 95% C.I. = 0.37 – 0.84) were lower than annual survival rates of spotted owls in unburned landscapes at the South Cascades (0.85, 95% C.I. = 0.83 – 0.88) and all other study areas (0.75 – 0.91, SE = 0.01 – 0.05) included in the last spotted owl meta-analysis (Anthony et al. 2006). Furthermore, post-fire annual survival estimates were lower than apparent survival estimates reported for California spotted owls (*Strix occidentalis occidentalis*) 0.81 – 0.88 (SE = 0.02 – 0.02) (Franklin et al. 2004), 0.827 (SE = 0.01) (Blakesley et al. 2001), 0.795 (SE = 0.01) (Seamans et al. 2001) and Mexican spotted owls 0.814 and 0.832 (SE = 0.00 – 0.02) (Seamans et al. 1999). In addition, owls outside fire boundaries had higher survival (1.00, 95% C.I. = 1.00 – 1.00) than owls affected by wildfire in this study, although my sample of owls in unburned landscapes was small.

Estimates of survival for the entire study (19 months) also supported my initial prediction, and indicated that owls outside of fires had higher survival (1.00, 95% C.I. = 1.00 – 1.00) than owls displaced by fire or within fire boundaries (0.33, 95% C.I. = 0.12 – 0.64). Study long survival rates declined over time, which may indicate that the effects of fire were compounded over time, potentially due to increased tree mortality over time

(Gaines et al. 1997), which further degraded owl habitat. These results indicated that wildfire and subsequent salvage logging negatively impacted spotted owl survival, even though previous research indicated minimal short-term impacts of wildfire on survival (Bond et al. 2002).

Initially, I predicted that high severity wildfire and salvage logging individually would decrease spotted owl survival. Due to insufficient sample sizes I was unable to determine if this prediction was supported by the data, so further research is needed to examine the effects of high severity wildfire and salvage logging on spotted owl survival. While I was unable to model the effects of wildfire and salvage logging on survival, previous research in unburned landscapes allows for general predictions to explain the low survival rates in this study. Low severity wildfire degraded spotted owl habitat through the removal of coarse woody debris, understory vegetation, and a multi-layered canopy (see Thomas et al. 1990 for description of spotted owl habitat), which may have negatively impacted spotted owl survival. High severity fire and salvage logging reduced the amount of suitable habitat and increased the amount of unsuitable habitat available to owls. Spotted owl survival rates were positively associated with increased amounts of old and mature forest in other studies (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005) and negatively associated with increased amounts of unsuitable habitat (Blakesley et al. 2005). Therefore, I hypothesize that habitat loss to high severity wildfire and clear-cut salvage logging jointly contributed to the low survival rates observed in this study, although I was unable to separate the effects of these 2 factors.

Survival of territorial raptors is often influenced by prey abundance (Southern 1970, Newton 1979, Wenland 1984, Steenhof et al. 1997, Brommer et al. 1998), and survival rates of owls in my study were likely influenced by prey abundance. While I did not estimate abundance of small mammals following wildfire I investigated post-fire owl diets by examining prey remains in regurgitated pellets. Results indicated that owl diets were dominated by woodrats (*Neotoma* spp.) and northern flying squirrels (*Glaucomys sabrinus*) (Appendix I), as would be expected for this area (Forsman et al. 2004). These data indicated that owl diets were comprised predominately of preferred prey items following wildfire, but the abundance of prey was unknown. Although I have no direct evidence of decreased prey abundance following wildfire, the severely emaciated condition of most owls submitted for necropsy suggested that owls struggled to obtain food resources in post-fire landscapes. Furthermore, the large home ranges of spotted owls in this study (see Chapter 5, this thesis) may have decreased survival rates as these owls may have passed an energetic threshold by using large areas. An additional hypothesis that I was unable to investigate was if transmitters influenced the ability of owls to capture prey. Furthermore, barred owls likely had little impact on survival estimates in my study because only 1 barred owl was detected at the Quartz and Timbered Rock Fires in 4 years of post-fire demographic surveys.

While my study was the first to directly estimate post-fire survival rates of spotted owls, the results may not translate to other post-fire landscapes because my sample was not selected randomly. The majority of my sample came from the Timbered Rock Fire which was dominated by a checkerboard land ownership pattern of private and federal ownership. Most of the private lands within the fire were salvage logged, which led to high levels of fragmentation and large areas of unsuitable habitat throughout the landscape. This potentially exacerbated or confounded the effects of wildfire on survival rates in this study and limited the scope of my inferences. Without results to indicate the effects of post-fire habitat on survival, I am unable to draw direct conclusions as to how different fire severities and subsequent salvage logging influenced survival individually.

CHAPTER 5

NORTHERN SPOTTED OWL HOME-RANGE SIZE AND COMPOSITION IN POST-FIRE LANDSCAPES OF SOUTHWESTERN OREGON

Darren A. Clark

INTRODUCTION

Northern spotted owls (*Strix occidentalis caurina*, hereafter spotted owl) are forest dwelling, territorial owls with large home ranges (Forsman et al. 1984, Thomas et al. 1990, Gutiérrez et al. 1995). Home ranges of spotted owls tend to increase in size with increasing latitude and elevation (Thomas et al. 1990). It is hypothesized that home ranges at lower elevations in the southern portion of the spotted owl's distribution are smaller because of increased abundance of large prey items (Carey et al. 1992), particularly woodrats (*Neotoma* spp.) in southwestern Oregon (Zabel et al. 1995). Decreased home range sizes of spotted owls are often associated with increased amounts of older forest (Carey et al. 1992, Glenn et al. 2004, Hamer et al. 2007). Furthermore, habitat fragmentation is hypothesized to increase home ranges of spotted owls (Carey and Peeler 1995). Between 1994 and 2003, wildfire became the leading cause of spotted owl habitat loss on lands administered by the Federal Government (Davis and Lint 2005) yet, little is known about the impacts of wildfire on the home range size of spotted owls.

In general, stand-replacing wildfires may eliminate large patches of old-growth forest, which may cause spotted owls to increase their home ranges. In addition, wildfire may reduce the vertical structure and complexity of forest stands and degrade the overall quality of the stand (see Thomas et al. 1990 for description of spotted owl habitat), which may force owls to use larger areas to meet their habitat requirements. Furthermore, wildfire may force spotted owls to shift habitat use to incorporate areas of unburned habitat (Bevis et al. 1997). High severity wildfire and salvage logging likely increase forest fragmentation throughout the landscape. Therefore it is expected that as suitable habitat is lost to wildfire and salvage logging, home ranges of spotted owls will increase.

Consequently, home ranges of spotted owls in burned landscapes may serve as a proxy for identifying post-fire territory sizes to ensure that sufficient levels of spotted owl habitat are protected during post-fire land management activities.

To investigate the effects of wildfire on home-ranges of spotted owls, I monitored owls in a post-fire landscape using radio-telemetry. The objectives of the study were to: (1) compare home ranges of spotted owls before and after wildfire and inside and outside burned areas, (2) delineate the core area of each owl within their home range, and (3) use habitat- and fire-specific covariates to test hypotheses about the effects of fire on home range and core area sizes. I predicted that: (1) home ranges would be smaller before wildfire, (2) home ranges inside the fire boundaries would be larger than home ranges outside the fire, and (3) home ranges would increase as the proportion of high severity fire and salvage logging increased within the home range and as the proportion of nesting, roosting and foraging habitat declined.

METHODS

Owl Capture and Radio-telemetry

Owls were captured from September, 2004 through May, 2006 and fitted with 7.5 g backpack mounted radio-transmitters (Holohil Systems Ltd. Model RI-2C, Ontario, Canada) following established methods (Forsman 1983, Guetterman et al. 1991). Wherever telemetry was feasible, I radio-marked all resident adult spotted owls at the Timbered Rock and Quartz Fires and surrounding areas. Twenty-six adult spotted owls were radio-marked, with the majority of the sample (*n* = 23) at the Timbered Rock Study Area. I monitored owls a minimum of 12 months, unless transmitters failed or the owl died. Telemetry was conducted from the ground with a 2-element yagi antenna and

Telonics model TR-2 receiver (Telonics, Inc., Mesa, Arizona, USA) or Communication Specialists model R-1000 receiver (Communications Specialist, Inc., Orange, California, USA). Locations were obtained on alternate nights of the week, to reduce autocorrelation of locations, which allowed the collection of up to 5 nocturnal and 2 diurnal locations every 2 weeks.

Home-range Analysis

I used program KERNELHR to estimate 95% fixed kernel home-ranges using least squares cross validation (LSCV) to select the kernel bandwidth (Seaman and Powell 1996, Seaman et al. 1997, 1998). Kernel methods are frequently used and are generally considered the best home-range estimator (Kernohan et al. 2001). Furthermore, fixed kernels are preferred over adaptive kernels because they are less biased at outer contour levels and have better surface overlap when compared to the true distribution (Seaman et al. 1999). Recently, other methods (likelihood cross validation and plug in and solve the equation) have been suggested to select the kernel bandwidth over LSCV. The LSCV method performs better than alternatives with sample sizes > 50 (Horne and Garton 2006), as was often the case in this study. Plug-in and solve the equation bandwidth methods tended to outperform LSCV except when data points were clumped (Gitzen et al. 2006), which is often the case with spotted owl data.

Home-ranges were estimated for annual, breeding (1 March – 31 August) and nonbreeding seasons (1 September – 28 February) using telemetry locations with error polygons ≤ 2 ha. Annual home ranges were estimated for owls that were monitored at least 3 months each season, with a minimum of 30 locations each season. Seasonal home ranges were derived for individuals monitored a minimum of 3 months with > 30 locations, following the suggestion of Seaman et al. (1999). Core areas were estimated for owls with sufficient data to estimate an annual home range. Core areas were delineated in a subroutine of KERNELHR called PLTCON4 that estimated the "greater than average observation density" (>AOD) contour. The >AOD defined the area of the home range with location densities higher than the average location density of the individual (Seaman et al. 1997).

I used 2-sample t-tests (Ramsey and Schafer 2002:38) to test for differences in home ranges of owls in this study versus those in the Miller Mountain Telemetry Study (Anthony and Wagner 1998) prior to fire and between owls inside versus outside the fire perimeter. I used multiple linear regression (Ramsey and Schafer 2002:240) to investigate differences in home range sizes associated with biotic or abiotic factors. The full model included the following explanatory variables: length of hard edge, the proportion of nesting, roosting, and foraging habitat (NRF), roosting and foraging habitat (RF), high severity fire, salvage and early-seral stands within the home range, number of locations, and indicator variables for sex and area (inside or outside the fire). I used backwards elimination to remove non-significant variables from the full model, leaving a reduced model that included the most significant variables. Values of explanatory variables varied greatly between individual owls (Appendix J).

RESULTS

Home ranges of owls varied greatly with male owls tending to have larger home ranges than females (Table 5.1). Annual home range sizes ranged from 126 – 1015 ha. Breeding season home ranges were typically the smallest, ranging from 32 – 754 ha, and usually included areas close to the site center or nest tree. Non-breeding home ranges tended to be the largest (range 209 – 2307 ha), and often incorporated the entire breeding season range and additional areas. Annual home ranges were smaller than non-breeding home ranges because fixed kernel home range estimates were used. The density of locations during the non-breeding season was less concentrated around the site center. Therefore, the smoothing parameter for non-breeding season home ranges was large when compared to annual home ranges, which were influenced by the high density of locations around nesting centers during the breeding season.

Table 5.1. Estimates of 95% fixed kernel home ranges and core areas (ha) of individual spotted owls monitored during three distinct time periods at the Timbered Rock and Quartz fires, Oregon, USA.

Owl	Inside or Outside Fire	Home Range Estimate: Annual	Breeding	Non-Breeding	Core Area
Timbered Rock Fire					
Alco Rock Female	Inside	741	155	2307	18
Alco Rock Male	Inside	354	212	502	18
Flat Creek Female	Inside	256	90	531	19
Flat Creek Male	Inside	597	296	668	40
Gobblers Knob Female	Inside	883	612	1009	60
Gobblers Knob Male	Inside	950	539	1101	104
Hawk Creek Male	Inside	NA	NA	1692	NA
Hungry Elk Female	Outside	584	372	507	53
Hungry Elk Male	Outside	781	319	1099	90
Louis Creek Female	Outside	126	32	255	7
Louis Creek Male	Outside	142	88	220	6
Lower Morine Female	Outside	792	500	1133	88
Lower Morine Male	Outside	1015	613	1944	117
Miller Mountain Female	Inside	835	481	910	90
Miller Mountain Male	Inside	820	486	1095	58
Oliver Springs Male	Outside	580	564	488	46
South Boundary Female	Outside	497	370	NA	25
South Boundary Male	Outside	914	597	1198	43
Upper Timber Female	Inside	NA	NA	520	NA
Upper Timber Male	Inside	682	NA	593	91
Timbered Rock Female	Inside	NA	424	NA	NA
Timbered Rock Male	Inside	NA	755	NA	NA
Quartz Fire					
Glade Creek Male	Inside	498	298	573	24
Yale Creek Female	Outside	304	99	209	16
Mean (All Owls)		618	376	856	50
Mean (Owls Inside the Fire)		662	395	958	52
Mean (Owls Outside the Fire)		573	356	784	49
Range		126 - 1014	32 - 754	209 - 2307	6 - 117

Annual Home Ranges

Home ranges of spotted owls monitored during the Miller Mountain Telemetry Study prior to wildfire (n = 14, $\bar{x}$ = 331, range = 61 – 1264 ha) were on average 286 ha (95% C.I. = 82 – 491) smaller than home ranges in this study (n = 20, $\bar{x}$ = 618 ha, range 126 – 1015 ha) (t = -2.85, df = 32, p < 0.01). Following wildfire, there was little evidence of a difference in mean annual home range sizes of owls residing inside fires ($\bar{x}$ = 662, range = 256 – 950, *n* = 10) to owls outside of fires ($\bar{x}$ = 573, range = 126 - 1015, *n* = 10) (t = 0.72, df = 18, p = 0.48) during my study.

The regression model that best described differences in annual home range sizes included variables for area, RF habitat, NRF habitat, and hard edge. While the area, RF, and NRF variables were significant ($p < 0.05$, Table 5.2), they explained little variation in the data (R^2 for area = 0.03, RF habitat = 0.05, and NRF habitat = 0.02). The length of hard edge within the home range explained most of the variability in the data ($R^2 = 0.59$, Figure 5.1). Hard edge and the proportion of NRF habitat were negatively correlated (r = -0.44, p = 0.04) and likely indicated that as hard edge increased within the home range, NRF habitat decreased. After accounting for other variables in the model, home range size increased by 30.7 ha for every 1 km of hard edge added to the home range (95% C.I. = 25.5 – 35.9 ha).

Table 5.2. Model parameters and estimated coefficients from the best multiple linear regression model explaining differences in home range sizes of individual owls during three sampling periods at the Timbered Rock and Quartz Fires, Oregon, USA.

Home Range	Parameter	Value	SE	t-value	p-value	R-squared	F-statistic
Annual	Intercept	-948.33	198.29	-4.78	0.00	0.91	37.24, 4, 15
	Area[a]	152.63	59.60	2.56	0.02		
	Roosting and Foraging Habitat[b]	1067.30	389.35	2.74	0.02		
	Nesting, Roosting and Foraging Habitat[c]	1525.72	220.01	6.93	0.00		
	Hard Edge[d]	30.71	2.65	11.60	0.00		
Breeding	Intercept	67.53	90.27	0.75	0.46	0.87	37.25, 3, 17
	Locations[e]	2.66	1.13	2.36	0.03		
	Non-Suitable Habitat[f]	-729.27	151.55	-4.81	0.00		
	Hard Edge	25.14	2.39	10.52	0.00		
Non-Breeding	Intercept	-513.31	97.36	-5.27	0.00	0.97	264.8, 2, 18
	Nesting, Roosting, Foraging Habitat	1212.51	197.99	6.12	0.00		
	Hard Edge	32.07	1.42	22.61	0.00		

[a] Area: indicator variable defining owls with their site center inside or outside the fire perimeter.

[b] Roosting and Foraging: the combined proportions of low/unburned and moderate severity roosting and foraging habitat.

[c] Nesting, Roosting and Foraging: the combined proportions of low/unburned and moderate severity nesting, roosting and foraging habitat.

[d] Hard Edge: the total length of hard edge within the home range in meters.

[e] Locations: the number of locations gathered during sampling period for each individual owl.

[f] Non-Suitable Habitat: includes non-habitat, early seral stands, and salvage logged areas

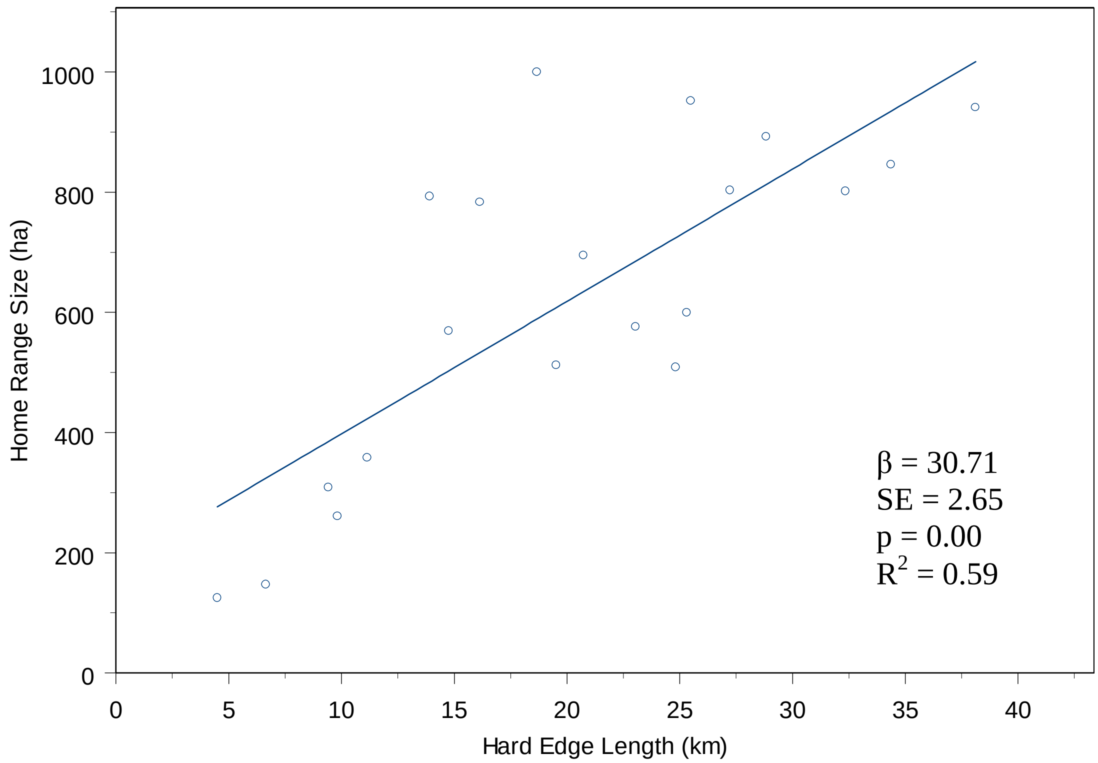

Figure 5.1. Linear relationship between annual spotted owl home range size to the amount of hard edge within the home range at the Timbered Rock and Quartz Fires and surrounding areas, Oregon, USA.

Breeding Season Home Ranges

Breeding season home ranges of owls inside fire boundaries ($\bar{x}$ = 395 ha, range 90 – 754 ha, *n* = 11) were similar to owls outside the fire ($\bar{x}$ = 356 ha, range 32 – 613 ha, *n* = 10) (t = 0.43, df = 19, p = 0.67). During the Miller Mountain Telemetry Study breeding season home ranges ($\bar{x}$ = 258 ha, range 32 – 1416 ha, *n* = 14) were not significantly different (t = -1.24, df = 33, p = 0.22) than breeding season home ranges for all owls in this project ($\bar{x}$ = 376 ha, range 32 – 754 ha, *n* = 21). However, the mean home range size from the Miller Mountain Study was strongly influenced by 1 individual with a home range of 1416 ha, which appeared to be an outlier. When this owl was censored from the analysis, the estimated mean breeding season home range size of owls during the pre-fire study was 169 ha, which was significantly smaller than owls in this study ($t = -3.23$, $df = 32$, $p < 0.01$).

Multiple linear regression indicated that the number of locations, proportion of early-seral habitat, and amount of hard edge within the home range influenced breeding season home ranges of spotted owls (Table 5.2). However, the number of locations ($R^2 < 0.00$) and proportion of early seral habitat ($R^2 < 0.00$) explained little variation in the data. Most of the variability was explained by the amount of hard edge within the home range ($R^2 = 0.67$). The regression coefficient for hard edge ($\beta = 25.14$, $SE = 2.39$, $p < 0.01$), suggested that as the amount of hard edge increased, home ranges increased.

Non-breeding Season Home Ranges

Non-breeding home ranges of owls residing within fire boundaries ($\bar{x} = 958$, range = 502 - 2307, $n = 12$) were not significantly different than owls outside fire boundaries ($\bar{x} = 784$, range = 209 - 1943, $n = 9$) ($t = 0.69$, $df = 19$, $p = 0.50$) in my study. During the Miller Mountain study ($n = 14$) owls had a mean home range of 377 ha (range 105 – 927 ha) during the non-breeding season, compared to owls in this project ($n = 21$) with a mean non-breeding home range of 883 ha (range 209 – 2307 ha). The difference in mean non-breeding home ranges after wildfire compared to before the fire was 506 ha (95% C.I. = 174.03 – 838.09 ha), which was significant ($t = -3.10$, $df = 33$, $p < 0.01$).

The regression model that best explained differences in non-breeding home ranges of spotted owls included the proportion of NRF habitat and the amount of hard edge within the home range (Table 5.2). The amount of hard edge explained most of the variation in home ranges ($R^2 = 0.90$), and the proportion of NRF habitat explained little

($R^2 = 0.03$). The relationship between non-breeding home range size and the amount of hard edge was positive ($\beta = 32.07$, SE = 1.42, $p < 0.01$) and suggested that home ranges increased as hard edge increased. In contrast to annual home ranges, the correlation between NRF habitat and the amount of hard edge in the home range was low ($r = -0.08$).

Core Areas

Core areas were estimated for owls that had sufficient data to calculate an annual home range ($n = 20$). In general, core areas were centered on historic or active nest trees and core areas of individuals of pairs tended to overlap. Some individuals had multiple core areas throughout their home range. The additional areas of concentrated use were often disjoint from the nesting core and likely indicated areas of preferred roosting and foraging habitat. Core areas of owls inside fire boundaries ($\bar{x} = 52$ ha, $n = 10$) versus owls outside of fires ($\bar{x} = 49$, $n = 10$) were not significantly different ($t = 0.18$, df = 18, $p = 0.86$). The regression model that best explained differences in core areas only included the amount of hard edge within the core area ($\beta = 13.49$, SE = 4.55, $p = 0.01$, $R^2 = 0.33$). For every 1 km increase in hard edge, core area size increased by 13.49 ha (95% C.I. = 4.57 – 22.41 ha, $p = 0.01$).

DISCUSSION

Home Ranges

Home ranges of spotted owls prior to fire were smaller than home ranges observed after fire, which may indicate that wildfire influenced home range size, as originally predicted. Previous research has suggested that spotted owl home ranges decreased as the amount of older forest within the home range increased (Carey et al. 1990, 1992, Glenn et al. 2004). Wildfire reduced the total amount of old forest and therefore likely contributed to larger home ranges in this study. Forest fragmentation has been hypothesized to increase home range sizes of spotted owls (Carey and Peeler 1995). Wildfire and salvage logging in the Timbered Rock study area increased fragmentation and may have contributed to the larger home ranges in this study.

If habitat loss and fragmentation due to wildfire and salvage logging increased home ranges, I would predict that owls outside fire boundaries would have smaller home ranges. Surprisingly, this prediction was not true, and several explanations exist for this circumstance. First, many of the owls outside the fire occupied a territory immediately adjacent to the fire and likely had portions of their territory consumed by wildfire. This likely reduced the amount high quality habitat available to these owls and increased fragmentation within individual territories. This likely caused increased home ranges (Carey et al. 1990, 1992, Carey and Peeler 1995) and shifted habitat use into areas of unburned habitat (Beavis et al. 1997). Second, 5 out of 10 owls included in the sample of owls outside the Timbered Rock Fire were displaced by the fire and shifted their territory to the nearest unoccupied site outside the fire. These owls may have displayed some level of "exploratory" behavior throughout their new territory in an effort to find prey. Third, there was a high density of spotted and barred owls (*Strix varia*) in 1 area outside the fire, which possibly led to increased competition and may have forced spotted owls to use larger areas. The year following the conclusion of telemetry activities, 1 pair of owls was not located, which suggested the high owl density in this area was not sustainable.

The best explanation for observing similar home range sizes of owls inside and outside the fire is that home ranges were influenced the most by the length of hard edge within the home range. The length of hard edge is a metric of habitat fragmentation, which is hypothesized to be detrimental to spotted owls in some areas (see review in Franklin and Gutiérrez 2002). Carey and Peeler (1995) hypothesized that the effects of forest fragmentation are similar to losing a preferred prey resource, which may force owls to use larger areas to obtain resources. Several owls outside the fire had the highest observed amounts of hard edge within their home range due to previous timber harvest activities. The large amounts of hard edge in these territories often exceeded the amounts of owls within the fire boundaries. Therefore, habitat fragmentation created by wildfire or timber harvest likely had the greatest impact on home ranges of spotted owls in this study.

Home ranges in this study were not directly influenced by the proportion of NRF habitat within the home range as reported in other studies (Carey et al. 1990, 1992, Glenn et al. 2004, Hamer et al. 2007). Although NRF habitat didn't appear to directly influence home ranges in this study, I did observe a negative correlation between edge and NRF habitat ($r = -0.44$, $p = 0.04$). Increased edge contributed to increases in home range size and increased edge likely indicated decreased amounts of NRF habitat. Therefore, I indirectly observed home ranges increasing as NRF habitat decreased. Overall, I found a weak relationship between the proportions of late-seral forests and home range size, which were similar to the results of Zabel et al. (1995), who found that home ranges were heavily influenced by woodrat (*Netoma* spp.) abundance. While I did not estimate woodrat abundance in this study, I assume owls may be responding to prey abundance following wildfire, particularly woodrats, which are the dominate prey species in this physiographic province (Solis and Gutiérrez 1990, Ward et al. 1998), but inference on this assumption is beyond the scope of my study.

Home ranges were larger following wildfire in my study, but high severity wildfire and salvage logging were not important variables influencing home ranges as initially predicted. The home range estimates in this study were from fixed kernel methods, which are based on density functions (Van Winkle 1975). Therefore, spotted owl use dictates the size and distribution of the home range with some level of habitat selection occurring within the home range (Cooper and Millspaugh 2001). Non-preferred habitats typically occurred infrequently within fixed kernel home ranges and they tend to be dominated by frequently used habitat; therefore, the power to detect the influence of infrequently used habitats on home ranges was small. Home range estimators that incorporate larger amounts of unsuitable habitat (adaptive kernel or minimum convex polygon) may have greater power to determine the impacts of habitat on home range size, but I did not examine these relationships.

Core Areas

Core use areas of spotted owls in this study were often centered on historic or active nest trees in areas of the best available habitat. The only variable I measured that influenced core size was the amount of hard edge within the core. The effects of forest fragmentation within the core area are likely similar to the effects within the home range, but may be compounded by the fact that spotted owls spend a disproportionate amount of time in these areas (Forsman et al. 1984, Solis and Gutiérrez 1990). Loss of late-seral habitat near nest sites was hypothesized to generate negative impacts on survival and reproduction (Bart 1995, Raphael et al. 1996). Core area was not influenced by fire severity or habitat features, which is not surprising as spotted owls select the oldest and most structurally diverse stands as their nesting cores (Ripple et al. 1991, 1997, Lemkuhl and Raphael 1993). Furthermore, owls in this study had relatively small core areas (all less than 100 ha). Swindle et al. (1999) found that as the radius from site center declined, the proportion of late-successsional forest increased, indicating that spotted owl site centers were located in the best available habitat within their territory. Consequently, the composition of core areas among owls was similar with very little of the core comprised of unsuitable habitat, which would leave little power to detect differences in core areas.

CHAPTER 6

NORTHERN SPOTTED OWL HABITAT SELECTION IN POST-FIRE LANDSCAPES OF SOUTHWESTERN OREGON

Darren A. Clark

INTRODUCTION

Northern spotted owls (*Strix occidentalis caurina*, hereafter spotted owl) predominately nest, roost and forage in mature and old-growth forests in the northern part of their range (Forsman et al. 1984, 2005, Carey et al. 1990, 1992). Nest and roost sites generally have greater proportions of old and mature forests than the surrounding landscape (Ripple et al. 1991, 1997, Lemkuhl and Raphael 1993). Forest stands used by spotted owls tend to have dense canopies, high proportions of mature and old trees, diverse structural composition, large amounts of down woody debris and increased numbers of snags (Forsman et al. 1984, Thomas et al. 1990, Hershey et al. 1998, North et al. 1999, Irwin et al. 2000). It has been suggested that sustainability of these habitats decreased in the latter part of the 20th century due to active fire suppression, which resulted in the build up of ladder fuels and dense stands (Agee 1993, MacCraken et al. 1996, Everett et al. 1997, Taylor and Skinner 1997, Spies et al. 2006), and potentially created additional spotted owl habitat.

Within the dry forest provinces of the Pacific Northwest, active fire suppression has resulted in densely stocked stands, which has probably increased the risk of stand-replacing wildfires (Agee and Edmonds 1992, Agee 1993, Lee and Irwin 2005, Spies et al. 2006). Furthermore, forest structure may have influenced the severity and scale of wildfire, with more severe fires occurring in structurally complex and densely stocked forest stands due to increased fuel loads and ladder fuels (Agee 1993, Sensenig 2002), although additional factors influence fire severities. Increased fuel loads may further exacerbate the effects of wildfire on spotted owls as large tracts of suitable habitat may be lost to wildfire. Within the range of the northern spotted owl, the leading cause of habitat loss on lands administered by the Federal Government from 1994 – 2003 was stand-replacing wildfire (Davis and Lint 2005). Stand-replacing wildfire is a threat to the long-term conservation of spotted owls and their habitat within the dry forest provinces of southwest Oregon and northwest California (Spies et al. 2006). In addition to stand replacing fire, the greatest impact of wildfire on spotted owls has been the alteration of habitat (McMahon and deCalesta 1990, Agee 1993) and changes in prey abundance following wildfire.

Currently, little is know about habitat selection of spotted owls in recently burned landscapes, but the large body of spotted owl research in unburned landscapes allows for general predictions regarding the effects of wildfire on habitat use. Increases in spotted owl home range size have been associated with declines in the amount of high quality habitat (Carey et al. 1990, Carey and Peeler 1995), and home ranges may increase as suitable habitat is lost to wildfire. Consequently, habitat use should shift outside of burned areas (Bevis et al. 1997) to make use of the best available habitat. Spotted owls have consistently selected the oldest and most structurally diverse habitat throughout most of their range (Forsman et al. 1984, 2005, Thomas et al. 1990, Carey et al. 1992, Glenn et al. 2004, Hamer et al. 2007). Wildfires are likely to consume large amounts of down woody debris, understory vegetation and snags which may reduce the quality of nesting, roosting and foraging habitat available to owls (Forsman et al. 1984, 2004, Bart 1995, Gaines et al. 1997, Raphael et al. 1996) in the short-term and may force owls to use less desirable habitats. Over time, low and moderate severity fires may create snags and down woody debris and provide benefits to owls in the future.

Given that spotted owls are listed as a threatened subspecies (U.S. Fish and Wildlife Service 1990), it is essential to determine habitats that are selected following wildfire to ensure these habitats are protected during land management activities when conservation of spotted owls is the primary objective. To understand the effects of wildfire on spotted owl habitat selection, I monitored spotted owls in a post-fire landscape using radio-telemetry. The objectives of the study were: (1) evaluate post-fire habitat selection of spotted owls at landscape and home range scales, and (2) compare stand level, post-fire habitat features of owl cores to similar stands within home ranges. I predicted that: (1) owls would select the oldest and most structurally diverse forest stands with the lowest fire severities within the landscape and home range, (2) salvaged logged stands and stands that burned with a high severity would be avoided by spotted owls, (3) owls would select areas closer to hard edges and streams than at random, (4) use of elevation, aspect or roads would be random, and (5) owl core areas would be more structurally diverse and have less fire damage than similar stands within the home range.

METHODS

Owl Capture and Monitoring

Owls were captured and fitted with 7.5 g backpack mounted radio-transmitters from September, 2004 through May, 2006 (Holohil Systems Ltd. Model RI-2C, Ontario, Canada) following established methods (Forsman 1983, Guetterman et al. 1991). Wherever telemetry was feasible, I radio-marked all adult spotted owls at the Timbered Rock and Quartz Fires and surrounding areas. During this project, I radio-marked 26 adult spotted owls, and the majority of the sample was located at the Timbered Rock

Study Area (Table 6.1). Owls were monitored a minimum of 12 months, unless the transmitter failed or the owl died prior to one year of monitoring (Appendix K).

Table 6.1. Individual northern spotted owls radio-tagged and included in the assessment of post-fire home range and habitat use at the Timbered Rock and Quartz Fires, Oregon, USA.

Site Name	Owls Captured	Date Captured	Inside/Outside Fire
Timbered Rock Fire			
Alco Rock	Pair	♂ - 09/04 ♀ - 02/05	Inside
Flat Creek	Pair	♂ - 03/05 ♀ - 09/04	Inside
Miller Mountain	Pair	♂ - 09/04 ♀ - 09/04	Inside
Upper Timber Creek	Pair	♂ - 09/04 ♀ - 09/04	Inside
Gobblers Knob	Pair	♂ - 09/04 ♀ - 09/04	Inside
Hungry Elk	Pair	♂ - 03/05 ♀ - 03/05	Outside
Lower Morine	Pair	♂ - 02/05 ♀ - 02/05	Outside
South Boundary	Pair	♂ - 03/05 ♀ - 03/05	Outside
Oliver Springs	Pair	♂ - 03/05 ♀ - 03/05	Outside
Louis Creek	Pair	♂ - 09/04 ♀ - 09/04	Outside
Hawk Creek	Male	♂ - 09/05	Inside
Timbered Rock	Pair	♂ - 05/06 ♀ - 05/06	Inside
Quartz Fire			
Yale Creek	Pair	♂ - 04/05 ♀ - 06/05	Outside
Glade Creek	Male	♂ - 04/05	Inside

Telemetry was conducted from the ground using a 2-element yagi antenna and Telonics model TR-2 receiver (Telonics, Inc., Mesa, Arizona, USA) or Communication Specialists model R-1000 receiver (Communications Specialist, Inc., Orange, California, USA). Telemetry stations were stored on a laptop or temporarily marked with a Garmin e-Trex handheld GPS unit (Garmin International, Inc. Olathe, Kansas, USA). During a period of 1 hour or until a location was obtained, compass bearings from a minimum of 3 telemetry stations were taken to the azimuth of the strongest telemetry signal. Nocturnal telemetry locations were gathered from 1 hour after sunset to 1 hour before sunrise on alternate nights of the week, to reduce autocorrelation of locations, and 1 day roost location was collected each week. This schedule allowed the collection of up to 5 nocturnal and 2 diurnal locations every 2 weeks. Over the course of the study, 3,014 individual telemetry locations were recorded. In the event that an owl could not be located from the ground, aerial searches were conducted from fixed-wing aircraft operated by the Oregon State Police (OSP). If the owl could not be located from the air, it was assumed the transmitter had failed or the owl had emigrated from the study area and was subsequently no longer monitored.

Owl locations were estimated in program XYLOG (Dodge and Steiner 1986), which generated an estimated location and 95% confidence ellipse based on the standard deviation of bearing intercepts around a mean location. All estimated locations had confidence ellipses $\leq$ 2.0 ha. If a confidence ellipse $\leq$ 2.0 ha could not be obtained in 1 hour, or if the owl moved, additional bearings were taken and a new location estimated. Accuracy assessment of the radio-telemetry system was conducted by placing transmitters in the field and having uninformed observers triangulate a location or observers would visually locate owls following a diurnal triangulation. The mean difference between estimated and actual locations was 136 m (SE = 29.49, n = 43), which is comparable to previous research on spotted owls (Carey et al. 1992 = 68 m, Zabel et al. 1995 = 111 m, Glenn et al. 2004 = 164 m, Forsman et al. 2005 = 140 m).

Habitat Selection Analyses

Habitat selection was analyzed at a landscape and home range scale by determining selection or avoidance of cover types over a reference habitat and through the comparison of odds ratios from logistic regression analysis (Rosenberg and McKelvey 1999). Cover types included; (1) non-habitat, (2) early seral habitat, (3 - 5) roosting and foraging (RF) habitat with low/unburned, moderate, or high severity burn, (6 – 8) nesting, roosting and foraging (NRF) habitat with low/unburned, moderate, or high severity burn, and (9) salvage logged areas (see Chapter 2, Table 2.1 for definitions). In all analyses, early seral habitat was the reference for odds ratio comparisons, because it was commonly available and is not a preferred habitat of spotted owls (Thomas et al. 1990). Several abiotic factors were also considered in habitat selection models including; (1) distance (m) to nearest perennial stream, (2) distance (m) to nearest road, (3) distance (m) to hard edge, (4) elevation (m), and (5) aspect (degrees). Logistic regression was conducted in SAS (SAS Institute Inc., Cary, NC, USA), by comparing telemetry locations to random locations throughout the landscape or home range. Model selection was conducted by comparing ΔAIC values and Akaike weights of candidate models (Burnham and Anderson 2002). The model with the lowest AIC was assumed the best and used to interpret results. Nocturnal and diurnal locations were pooled due to small sample sizes of diurnal locations. Furthermore, I assumed that nocturnal and diurnal locations both represent habitat selection by spotted owls, but factors that influence selection during roosting and foraging may be different (Forsman et al. 1984) and were not accounted for in my analysis.

Landscape Scale Selection

Landscape scale habitat selection was analyzed for owls at the Timbered Rock Fire, because all known spotted owls were captured within the study area, which provided a representative sample of use throughout the landscape. Three separate analyses were conducted to compare habitat selection of all owls included in the study area (n = 23), owls with site centers located within the fire boundaries (n = 13), and owls with site centers located outside fire boundaries (n = 10). Locations of all individuals within each group were pooled to define habitat use. Habitat availability was defined by delineating a polygon around the 100% minimum convex polygon home ranges of each analysis group. Ten-thousand random points (Nielson et al. 2003) were generated in ArcGIS 9.1 to describe available habitat and characteristics of abiotic features for each analysis group. The analysis was primarily exploratory, because information on post-fire habitat selection of the species was lacking to guide my hypotheses. Therefore, I generated a large set of *a priori* models that may be responsible for habitat selection of spotted owls in burned landscapes (Table 6.2). Analysis occurred in a multi-step process by first determining the best cover type model, then the best abiotic factor model and finally the best combination of the 2. I hypothesized that spotted owls would select the most structurally diverse and oldest conifer stands with the lowest fire severity and avoid areas with complete overstory canopy mortality. In addition, I hypothesized that spotted owl locations would be randomly distributed in regards to hard edges, streams, roads, elevation and aspect throughout the landscape.

Table 6.2. *A priori* models used to test post-fire habitat selection of spotted owls at multiple spatial scales with logistic regression at the Timbered Rock and Quartz Fires, Oregon, USA, 2004 - 2006.

Habitat Related Model Parameters	Abiotic Factor Model Parameters
Low[a] Moderate[a] High[a] Salvage	Hardedge[h]
Low Moderate High	Road[i]
Low Moderate	Elevation
Low	Aspect[j]
RF[b] NRF[c] High Salvage	Stream[k]
RF NRF High	Stream Elevation
RF NRF	Hardedge Stream
NRF	Hardedge Elevation Stream
Non-suitable[d] Suitable[e]	Stream Road Aspect
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage	Stream Road Elevation
RFLow[f] RFMod RFHigh NRFLow[g] NRFMod NRFHigh Salvage	Stream Road
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh	Stream Road Elevation Hardedge
RFLow RFMod NRFLow NRFMod High Salvage	Stream Road Hardedge
RFLow RFMod NRFLow NRFMod High	Hardedge Road Elevation Aspect Stream
RFLow RFMod NRFLow NRFMod	
RFLow NRFLow	
NRFLow NRFMod	
NRFLow	

[a] Low, Moderate and High: fire severity regardless of habitat type.

[b] RF: roosting and foraging habitat of low or moderate severity.

[c] NRF: nesting, roosting and foraging habitat of low or moderate severity.

[d] Non-suitable: high severity or salvage logged stand in addition to non-habitat.

[e] Suitable: moderate or low/unburned severity - roosting and foraging, or nesting roosting and foraging stand.

[f] RFLow: roosting and foraging habitat with a low/unburned severity (Mod and High: moderate and high severity).

[g] NRFLow: nesting, roosting, and foraging habitat with a low/unburned severity (Mod and High: moderate and high severity).

[h] Hardedge: Distance (m) of telemetry/random location from nearest hard edge.

[i] Road: Distance (m) of telemetry/random location from nearest road.

[k] Aspect: Position of telemetry/random location in degrees (0 - 360).

[k] Stream: Distance (m) of telemetry/random location from nearest perrenial stream.

Home Range Scale Selection

Habitat selection within individual territories was assessed at the Timbered Rock and Quartz fires for owls with sufficient telemetry data to estimate fixed kernel home ranges. Habitat selection was analyzed for annual (*n* = 20), breeding (*n* = 21) (March 1st – August 31st), and non-breeding seasons (*n* = 21) (September 1st – February 28th). Annual habitat selection was estimated for owls that were monitored a minimum of 3 months each season and had at least 30 locations within each season. Seasonal estimates of habitat selection were generated because spotted owls are a territorial species that often focus habitat use around a site center during the breeding season and more diverse use during the non-breeding season (Forsman et al. 1984).

Habitat availability was estimated by generating a 99.9% fixed kernel utilization distribution in program KERNELHR (Seaman et al. 1998) for each season and owl. The 99.9% utilization distribution is the closest approximation of the area that owls are expected to be found within their home range, because KERNELHR is not capable of calculating a 100% utilization distribution. One thousand random points were generated in ArcGIS 9.1 to describe available habitat and abiotic habitat features within each individual's territory following the suggested minimum 5:1 ratio of available to used points (Cooper and Millspaugh 1999, 2001), as all owls in this study had < 200 locations.

Habitat selection at the home range scale was analyzed following central-place foraging methodology (Rosenberg and McKelvey 1999) for annual and breeding season analyses because spotted owls often return to a central location within their territory (Carey and Peeler 1995, Rosenberg and McKelvey 1999). This approach assumes that the probability of habitat use will decline in a simple density to distance function as owls move away from the site center. Two separate distance functions were compared, a linear function and a third order polynomial function that allowed non-linear trends (Rosenberg and McKelvey 1999). Spotted owls frequently use the site center during the non-breeding season but relative use declines (Forsman et al. 1984) and use is assumed to be more random throughout the home range. Therefore, distance from site center was not modeled during the non-breeding season.

Home range scale habitat selection was analyzed using a similar set of *a priori* models as the landscape scale analysis (see Table 6.2), except distance functions were also included. During the analysis several models failed to converge due to quasi-complete separation of data points, which indicated that individuals had habitats available to them that were never used. To obtain model convergence, I generated a "false" use point, which allowed representation of a very low level of use (Gervais et al. 2003). To determine relative importance of individual parameters in home range scale habitat selection, I calculated the number of times parameters appear in the top model of individual owls. Within each season, I split the analysis into 2 groups; owls within the fire boundary, and owls outside the fire, since habitat selection is likely to vary between the two groups and between seasons. In addition to assessing habitat selection using logistic regression, I compared habitat use versus availability with the home range of individual owls using the method described by Neu et al. (1974) (Appendix L).

At the home range scale, I hypothesized that spotted owls would select the oldest forests with the lowest level of fire severity and avoid high severity burns and salvage logged areas. Furthermore, I hypothesized that owls would select areas closer to streams and lower in elevation, which are associated with riparian areas that likely had decreased fire severity and increased structure (Reeves et al. 2006). Owls should also use areas closer to hard edges as these areas likely have increased prey abundance (Carey and Peeler 1995, Zabel et al. 1995). North and east-facing slopes were hypothesized to be selected by owls over south and west-facing slopes, as south-facing aspects should have received more severe fires (Agee 1993, Gaines et al. 1997, Taylor and Skinner 1997). Spotted owls should avoid roads because these areas have likely endured higher levels of human disturbance.

Comparison of High and Low Use Areas

To examine forest structure and fire severity characteristics of frequently used stands within the fire boundaries, high and low use plots of similar habitat and fire severity composition within the home range were compared. Ten owls (5 pairs) had sufficient telemetry data to estimate core areas (high use) within the Timbered Rock Fire. For each individual, a sample of 5 high use and 5 low use plots were collected. Each plot consisted of an 18 m fixed radius plot and all trees > 15 cm diameter at breast height (DBH) were measured and identified to species and status regarding live or fire killed. Any trees < 15 cm DBH were counted and broken into 4 groups, live and dead conifers, and live and dead hardwoods. Down woody debris was measured using a line transect method (Van Wagner 1968) along 4, 15 m transects running in each cardinal direction from the plot center. Overstory canopy cover was estimated using a densitometer and averaging canopy cover values at 13 points within the plot (1 point at the plot center, and 3 points evenly placed in each cardinal direction). Ground cover was visually estimated at 5, 2.5 meter radius plots (1 plot at the site center and 1 plot 12 m from the plot center in each cardinal direction). Ground cover was estimated for 3 distinct heights, 0-1 m, 1-2 m, and 2-3 m and then averaged across plots. Fire severity was assessed using a modified Composite Burn Index (Key and Benson 1999a).

High and low use plots were pooled across owls due to small sample sizes, which resulted in a sample of 50 low and 50 high use plots. The analysis procedure was exploratory and inference from the results is limited. Graphical displays and two-sample t-tests were used to identify potential differences between high and low use plots, reducing the total number of variables tested in the final analysis. The remaining variables were then analyzed using logistic regression (Ramsey and Schafer 2002:583) by starting with a rich model and subsequently eliminating variables using a drop term function, in SPlus (Insightful Corporation, Seattle, WA, USA). The drop term function removed the variable that provided the greatest influence on the AIC value of the model until no additional improvement was seen.

RESULTS

Landscape Scale Selection

All Owls Within the Study Area

Twenty-three individual owls were included in the analysis of landscape scale habitat selection within and around the boundaries of the Timbered Rock Fire. Spotted owls used all habitats to varying degrees (Figure 6.1), although NRF habitat with little to no overstory canopy mortality was used disproportionately more. Several habitats (RF-Moderate, NRF – Low/Unburned, NRF – Moderate, and NRF – High) were used more frequently than available, while others (Non-habitat, Early-seral, RF – Low/Unburned, RF – High, and Salvage) were used less frequently than available. The best model for habitat selection of all owls at the Timbered Rock study area included all habitat and abiotic variables (Table 6.3, Appendix M1). There were no competing models, and the best model included all of the Akaike weight (1.00).

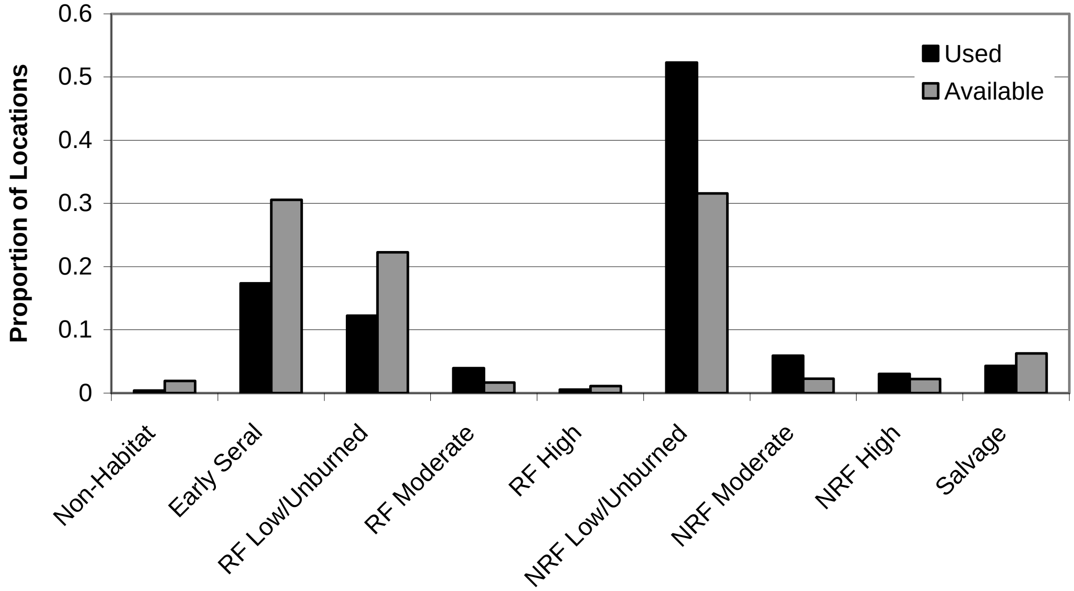

Figure 6.1. Proportions of used and available habitats for northern spotted owls monitored at the Timbered Rock Fire and surrounding areas from September, 2004 to August, 2006.

Table, 6.3. Model selection results for landscape scale post-fire habitat selection of spotted owls, in three distinct groups at the Timbered Rock Fire, September 2004 - August, 2006.

Group	Model	AIC	ΔAIC	Weight
All Owls	Nonhabitat, RFLow, RFMod, RFHigh, NRFLow, NRFMod, NRFHigh, Salvage, Stream, Road, Elevation, Aspect, Hardedge	11059.689	0.000	1.000
	RFLow, RFMod, RFHigh, NRFLow, NRFMod, NRFHigh, Salvage, Stream, Road, Elevation, Aspect, Hardedge	11101.231	41.542	0.000
Owls Inside Fire	Nonhabitat, RFLow, RFMod, RFHigh, NRFLow, NRFMod, NRFHigh, Salvage, Stream, Road, Election, Aspect, Hardedge	7704.633	0.000	0.986
	Nonhabitat, RFLow, RFMod, RFHigh, NRFLow, NRFMod, NRFHigh, Salvage, Stream, Road, Elevation, Hardege	7713.391	8.758	0.012
Owls Outside Fire	Nonhabitat, RFLow, RFMod, RFHigh, NRFLow, NRFMod, NRFHigh, Salvage, Stream, Road, Elevation, Aspect	6165.399	0.000	0.720
	Nonhabitat, RFLow, RFMod, RFHigh, NRFLow, NRFMod, NRFHigh, Salvage, Stream, Road, Elevation, Aspect, Hardedge	6167.290	1.891	0.280

The regression coefficients for salvage logged areas and RF habitats with low/unburned or high severity burn had p-values > 0.05 and 95% confidence intervals overlapping 1. This indicated these habitats were used in a similar fashion as early-seral forests throughout the study area (Table 6.4). Non-habitat was avoided throughout the study area (Odds = 0.18, 95% C.I. = 0.09 – 0.34). Spotted owls selected 4 habitats over the reference habitat including; RF habitat with a moderate severity burn and NRF habitat with all levels of fire severity. Within the study area, spotted owls were 2.91 times more likely (95% C.I. = 2.22 – 3.83, $p < 0.001$) to use RF habitat with a moderate severity burn, 3.61 times more likely (95% C.I. = 3.17 – 4.10, $p < 0.001$) to use NRF habitat with low/unburned severity, 3.50 times more likely (95% C.I. = 2.74 – 4.37, $p < 0.001$) to use NRF habitat with moderate severity burn, and 2.33 times more likely (95% C.I. = 1.75 – 3.09, $p < 0.001$) to use NRF habitat with high severity burn than early-seral forests. NRF habitats with moderate and high severity burn and RF with moderate severity burns were selected and used more frequently than available, but overall use of these habitats was relatively low.

Table 6.4. Parameter estimates for the best model explaining landscape scale habitat selection at the Timbered Rock Study Area, for all radio-tagged owls.

Parameter	Estimate	SE	p-value	Odds	95% C.I. Odds Ratio
Intercept	0.33	0.13	0.01	NA	NA
NonHabitat	-1.71	0.32	0.00	0.18	0.10 - 0.34
RFLow	0.07	0.08	0.42	1.07	0.91 - 1.25
RFMod	1.07	0.14	0.00	2.91	2.22 - 3.83
RFHigh	-0.42	0.29	0.14	0.66	0.37 - 1.15
NRFLow	1.28	0.07	0.00	3.61	3.17 - 4.10
NRFMod	1.24	0.12	0.00	3.46	2.74 - 4.37
NRFHigh	0.84	0.15	0.00	2.33	1.75 - 3.09
Salvage	0.16	0.12	0.17	1.17	0.93 - 1.48
Stream	0.00	0.00	0.00	1.00	0.99 - 1.00
Road	0.00	0.00	0.00	1.00	0.99 - 1.00
Elevation	0.00	0.00	0.00	1.00	0.99 - 1.00
Aspect	0.00	0.00	0.00	1.00	0.99 - 1.00
Hardedge	0.00	0.00	0.00	1.00	0.99 - 1.00

Elevation, aspect, and distance to perennial streams, hard edges and roads influenced habitat selection. Owls used areas closer to hard edges ($\bar{x}$ = 146.1 m, 95% C.I. = 140.7 – 151.5) than random ($\bar{x}$ = 153.7 m, 95% C.I. 150.7 – 156.6), but the estimated difference was only 7.5 m and was influenced by large sample sizes. The difference in distance to nearest road between random ($\bar{x}$ = 313.1 m, 95% C.I. = 304.5 – 321.6) and telemetry locations ($\bar{x}$ = 185.0 m, 95% C.I. = 177.6 – 192.4) was approximately 128 m. The mean elevation of telemetry locations was 817.7 m (95% C.I. = 812.5 – 822.8) compared to 862.1 m (95% C.I. = 858.0 – 866.4) for random locations, a mean difference of 44.5 m. The difference in aspect of random points ($\bar{x}$ = 176.4, 95% C.I. = 174.5 – 178.3) and owl locations ($\bar{x}$ = 162.2, 95% C.I. = 158.8 – 165.6) was 14.3 degrees, which was likely not biologically significant. Finally, random locations were on average 481.4 m (95% C.I. = 473.3 – 489.5) from perennial streams compared to 207.4 m (95% C.I. = 200.9 – 214.1) for used points, which was 273.9 m closer to streams than random.

Owls Within the Fire Perimeter

Thirteen spotted owls had their site centers located within the boundaries of the Timbered Rock Fire, and several owls occasionally foraged outside the fire perimeter, which allowed unburned portions of the landscape to be available for use. Owls residing inside the fire used all available habitat including moderate and high severity burns (Figure 6.2), although habitat use was dominated by low severity burns in NRF habitat. The best habitat selection model of spotted owls residing within the Timbered Rock Fire was the most complex (Table 6.3, Appendix M2), and there were no competing models. The Akaike weight of the top model was 0.97, which was over 80 times that of the second model.

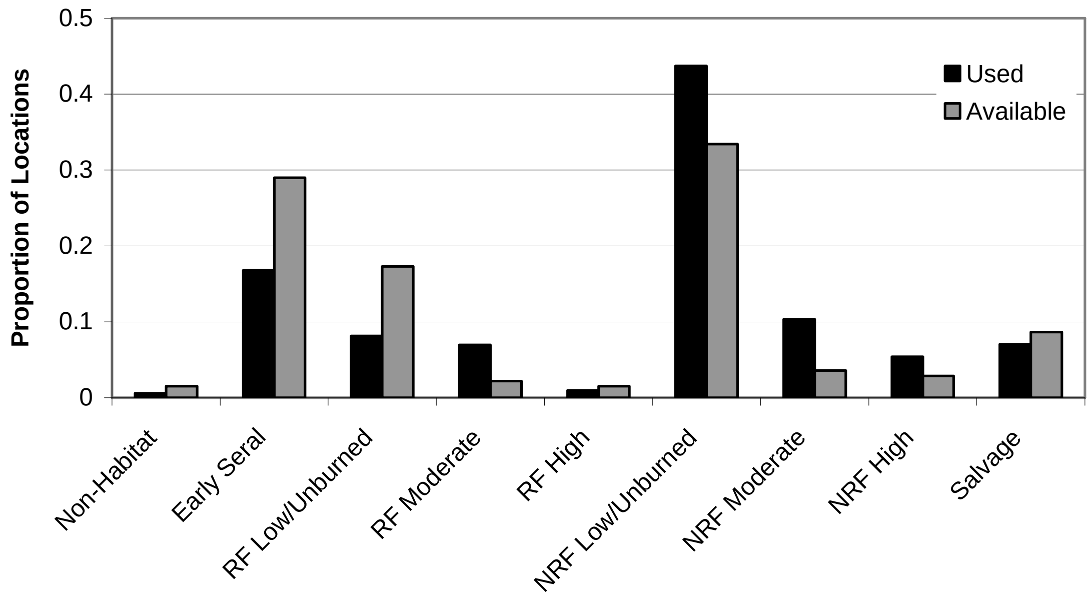

Figure 6.2. Proportions of used and available habitats for northern spotted owls residing within the boundaries of the Timbered Rock Fire from September, 2004 to August, 2006.

All habitat parameters included in the model had p-values less than 0.05, and 95% confidence intervals of odds ratios did not overlap 1.0 (Table 6.5), except RF habitat with a high severity burn. This habitat was scarce in the area and was used in a similar fashion to early-seral forests. Two habitats were avoided; non-habitat (Odds = 0.31, 95% C.I. = 0.15 – 0.62, p = 0.001) and RF habitat with a low/unburned severity (Odds = 0.79, 95% C.I. = 0.63 – 1.000, p = 0.049). Owls were 4.15 times more likely (95% C.I. = 3.14 – 5.48, p < 0.001) to use RF habitat with a moderate severity burn than early seral habitat. NRF habitats of any fire severity were selected, with low/unburned stands being 3.23 times (95% C.I. = 2.73 – 3.81, p < 0.001), moderate severity stands being 4.48 times (95% C.I. = 3.52 – 5.69, p < 0.001), and high severity stands being 3.58 times (95% C.I. = 2.67 – 4.80, p < 0.001) more likely used than early seral habitat. NRF with high severity burn was selected and used more frequently than available, but roughly 5% of locations fell within this habitat and suggested use of this habitat was limited. Finally, salvaged stands were 1.58 times more likely (95% C.I. = 1.23 – 2.02, $p < 0.001$) to be used than the early seral habitat.

Table 6.5. Parameter estimates for the best model explaining landscape habitat selection at the Timbered Rock Fire, for radio-tagged owls within the fire boundaries.

Parameter	Estimate	SE	p-value	Odds	95% C.I. Odds Ratio
Intercept	0.27	0.16	0.09	NA	NA
NonHabitat	-1.18	0.36	0.00	0.31	0.15 - 0.62
RFLow	-0.23	0.12	0.05	0.79	0.63 - 1.00
RFMod	1.42	0.14	0.00	4.15	3.15 - 5.48
RFHigh	0.01	0.28	0.98	1.01	0.58 - 1.76
NRFLow	1.17	0.09	0.00	3.23	2.73 - 3.81
NRFMod	1.50	0.12	0.00	4.48	3.52 - 5.69
NRFHigh	1.28	0.15	0.00	3.58	2.67 - 4.80
Salvage	0.46	0.13	0.00	1.58	1.23 - 2.02
Stream	0.00	0.00	0.00	1.00	0.99 - 0.99
Road	0.00	0.00	0.00	1.00	0.99 - 0.99
Elevation	0.00	0.00	0.00	1.00	0.99 - 0.99
Aspect	0.00	0.00	0.00	1.00	0.99 - 1.00
Hardedge	0.00	0.00	0.00	1.00	0.99 - 0.99

Salvage logged stands appeared to be selected over the reference habitat, but caution must be exercised when interpreting this result. For example, 109 telemetry locations were within salvage-logged areas, but visual inspection of the telemetry locations on aerial photos revealed that 65 (60%) of these locations were associated with riparian buffers, thinned areas, or patches of wildlife leave trees that are not delineated on habitat maps. Also, some of the locations in salvaged areas occurred prior to, or during active timber harvest, but the number of locations falling into this category was not quantified, because the exact date of timber harvest was unknown. Therefore, spotted owls did not select salvage logged areas, but used areas within salvaged stands that had live trees. Areas that received clear-cut salvage were rarely used.

All abiotic factors included in the best model were significant ($p < 0.05$, Table 3.10). The estimated difference in the distance to nearest road between random points ($\bar{x}$ = 309.3 m, 95% = 299.5 – 319.0) and owl locations ($\bar{x}$ = 165.8 m, 95% C.I. = 157.2 – 174.4) was 143.5 m. Spotted owl locations ($\bar{x}$ = 169.2 degrees, 95% C.I. = 164.9 – 173.4) were 4.5 degrees less in aspect on average than random points ($\bar{x}$ = 173.7 degrees, 95% C.I. = 171.8 – 175.6), which was not significant from a biological standpoint. Telemetry locations ($\bar{x}$ = 121.7 m, 95% C.I. = 116.4 – 126.9) were 35.4 m closer to hard edges than random locations ($\bar{x}$ = 157.1 m, 95% C.I. = 154.0 – 160.1). Spotted owls within the Timbered Rock Fire used areas ($\bar{x}$ = 822.2 m, 95% C.I. = 815.7 – 828.6) 80.4 m lower in elevation than random (mean = 902.6 m, 95% C.I. = 898.2 – 906.9). In addition, the estimated difference between random locations ($\bar{x}$ = 434.2 m, 95% C.I. = 426.7 – 441.8) and used locations ($\bar{x}$ = 199.4 m, 95% C.I. = 190.5 – 208.2) was 234.9 m from the nearest perennial stream.

Owls Outside the Fire Boundary

Ten owls inhabited areas adjacent to the Timbered Rock Fire; they used a variety of habitats, but were located infrequently within the fire (Figure 6.3). The best model included all the habitat and abiotic parameters except hard edge, which was included in the only competing model (Table 6.3, Appendix M3). The AIC weight of the top model was 0.72, which is almost 3 times that of the next model.

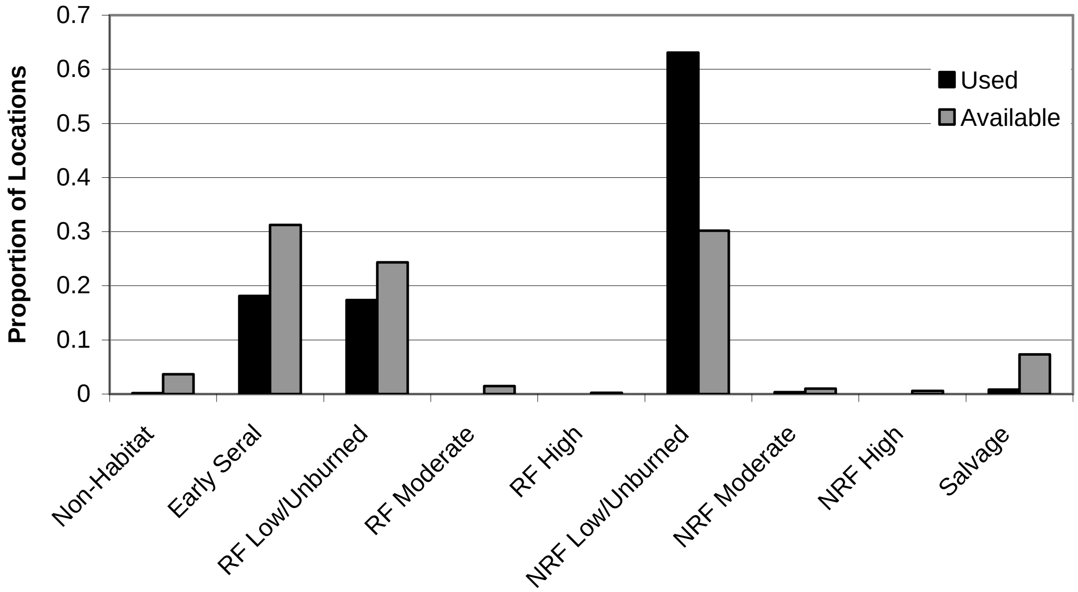

Figure 6.3. Proportions of used and available habitat for northern spotted owls residing outside the boundaries of the Timbered Rock Fire from September, 2004 to August, 2006.

Three habitat variables had p-values > 0.05 and confidence intervals that overlapped 1.0, which indicated that high severity RF habitat and moderate and high severity NRF habitats were used in a similar fashion to early-seral forests (Table 6.6). While these results indicated that the high severity RF and NRF habitats were used in a similar manner as early seral habitats, these habitats were scarce outside the fire and used so infrequently that reasonable odds ratios and confidence intervals could not be generated. Habitats that were avoided included; non-habitat, moderate severity RF habitat, and salvage logged areas. Spotted owls outside the fire were 0.01 times less likely (95% C.I. = 0.01 – 0.21, p < 0.001) to use non-habitat, 0.09 times less likely (95% C.I. = 0.01 – 0.65, p = 0.017) to use moderately burned RF habitat, and 0.22 times less likely (95% C.I. = 0.11 – 0.41, p < 0.001) to use salvage logged stands than early-seral habitat. Spotted owls were 1.44 times (95% C.I. = 1.17 – 1.77, p = 0.001) more likely to use RF habitat with a low/unburned severity and 4.10 times (95% C.I. = 3.44 – 4.87) more likely to use low/unburned stands of NRF habitat than early seral forests.

Table 6.6. Parameter estimates for the best model explaining landscape habitat selection at the Timbered Rock Fire for radio-tagged owls outside the fire boundaries.

Parameter	Estimate	SE	p-value	Odds	95% C.I. Odds Ratio
Intercept	-1.88	0.17	0.00	NA	NA
NonHabitat	-2.98	0.72	0.00	0.01	0.01 - 0.21
RFLow	0.36	0.11	0.00	1.44	1.17 - 1.77
RFMod	-2.41	1.01	0.02	0.09	0.01 - 0.65
RFHigh	-12.30	418.10	0.98	0.00	0.00 - 999.99
NRFLow	1.41	0.09	0.00	4.10	3.44 - 4.87
NRFMod	-0.95	0.52	0.07	0.39	0.14 - 1.07
NRFHigh	-12.70	250.70	0.96	0.00	0.00 - 999.99
Salvage	-1.54	0.33	0.00	0.22	0.11 - 0.41
Stream	0.00	0.00	0.00	1.00	0.99 - 0.99
Road	0.00	0.00	0.00	1.00	0.99 - 1.00
Elevation	0.00	0.00	0.00	1.00	1.00 - 1.00
Aspect	0.00	0.00	0.00	1.00	0.99 - 0.99

The top model included all abiotic factors and all variables were statistically significant. Telemetry locations ($\bar{x}$ = 812.0, 95% C.I. = 803.7 – 820.3) were on average 4.5 m lower in elevation than random ($\bar{x}$ = 816.4, 95% C.I. = 812.6 – 820.3), which was not biologically meaningful. Owl locations ($\bar{x}$ = 209.3, 95% C.I. = 196.7 – 221.9) were on average 78.3 m closer to roads than random points ($\bar{x}$ = 287.6, 95% C.I. = 281.7 – 293.5). Owl locations had a mean aspect of 153.3 degrees (95% C.I. = 147.9 – 158.7), and random locations had a mean of 170.4 degrees (95% C.I. = 168.5 – 172.3), which indicated that spotted owls selected north and east-facing slopes. Mean telemetry locations were 217.8 m (95% C.I. = 208.0 – 227.5) from a perennial stream, and random locations were 487.6 m (95% C.I. = 480.5 – 494.8) from the nearest stream. Telemetry locations were on average 269.9 m closer to streams.

Home Range Scale Selection

The proportions of used habitats varied greatly between individuals, especially within the fire boundary (Figure 6.4). Considering the large number of *a priori* models tested and the variability in proportions of used and available habitats among individuals, it was expected that the diversity of models explaining individual habitat selection would be substantial (Appendices N - P). As a result, I did not find a consensus model that described habitat selection among owls at a home range scale. Therefore, the relative importance of parameters was determined by calculating the number of times unique parameters appeared in the best model of individual owls.

Year Round Habitat Selection

Six variables frequently occurred in the top models of owls inside the fire, while 4 variables consistently occurred in the best model for owls outside the fire (Table 6.7). In addition, a polynomial distance function that described a non-linear decline in the probability of use as distance from site center increased was important for most owls (Figure 6.5), but one owl had a linear distance function. Additional variables occasionally occurred in the top model for individuals, but were not important in determining selected habitats among owls.

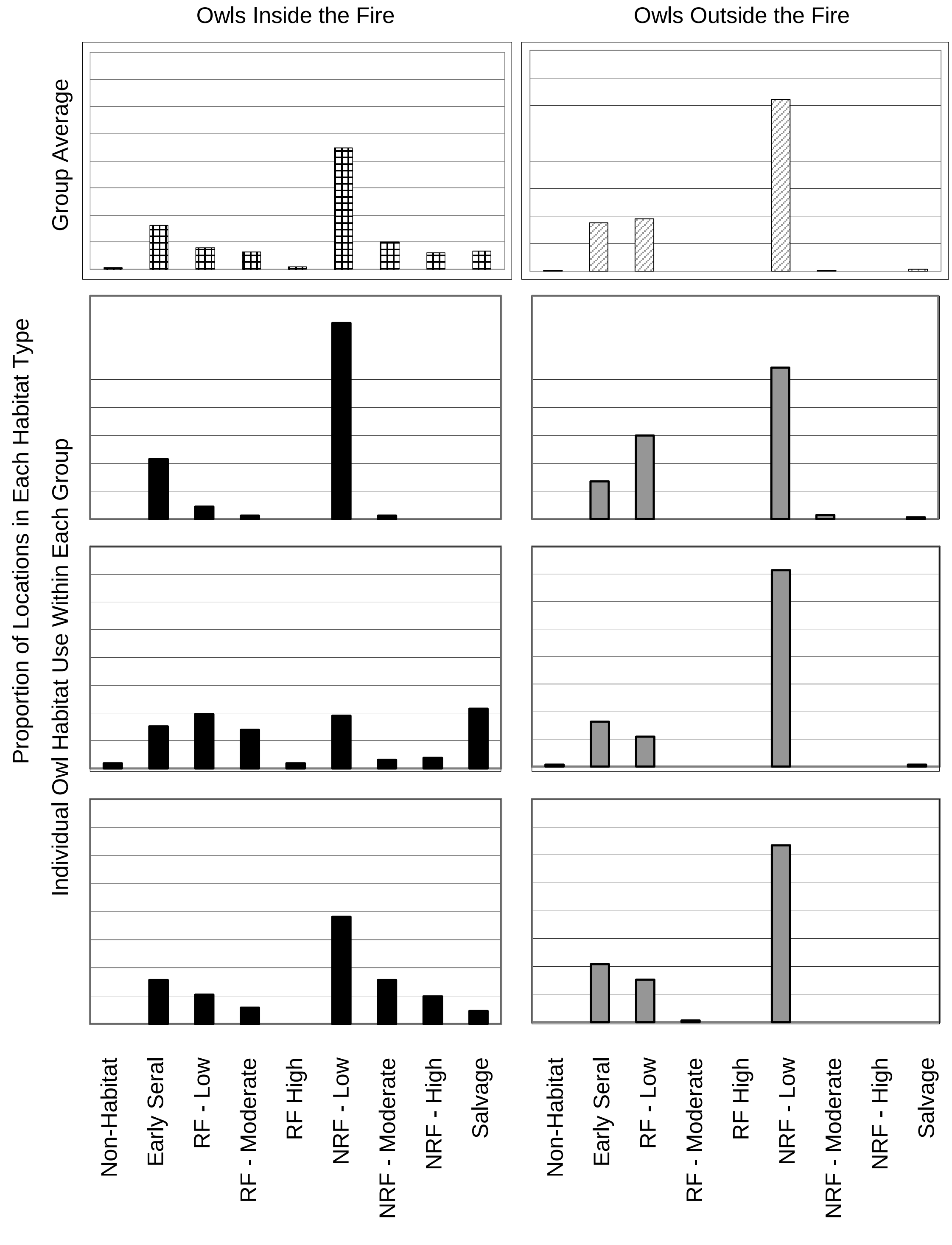

Figure 6.4. Visual representation of the variability in habitat use of individual spotted owls, comparing overall group habitat use of owls inside and outside the Timbered Rock Fire to 3 individuals within each group (Horizontal lines represent 10% increments).

Table 6.7. Relationships of parameters that frequently appear in the top model of annual habitat selection of individual spotted owls at a home range scale, at the Timbered Rock and Quartz Fires, September, 2004 to August, 2006.

Group	Parameter	Percent of Models	Relationship		
			Selected/Closer	Avoided/Further	Not Significant
Inside Fire	Distance * NRF - Low/Unburned[a]	20%	2	0	0
	NRF - Low/Unburned	60%	5	0	1
	NRF - Moderate	30%	0	0	3
	NRF - Low and Moderate	10%	1	0	0
	RF - Low/Unburned	30%	0	0	3
	RF - Moderate	30%	3	0	0
	Non-Suitable	20%	1	0	1
	Suitable	20%	2	0	0
	High Severity	10%	0	0	1
	Distance to Stream	40%	4	0	0
	Distance to Hard Edge	20%	2	0	0
	Used Lower Elevations	50%	5	0	0
Outside Fire	Distance * NRF - Low/Unburned	40%	3	0	1
	NRF - Low/Unburned	40%	2	0	2
	Non-Suitable	20%	0	1	1
	Suitable	20%	0	0	2
	Distance to Stream	20%	2	0	0
	Distance to Hard Edge	40%	1	0	3
	Distance to Road	10%	0	0	1
	Used Lower Elevations	60%	3	1	2

* All owls, except one, had a polynomial distance function included in the best model, indicating non-linear declines in the probability of use away from the site center.

a - This parameter indicates a decline in the probability of using NRF - Low/Unburned habitat as distance from site center increases.

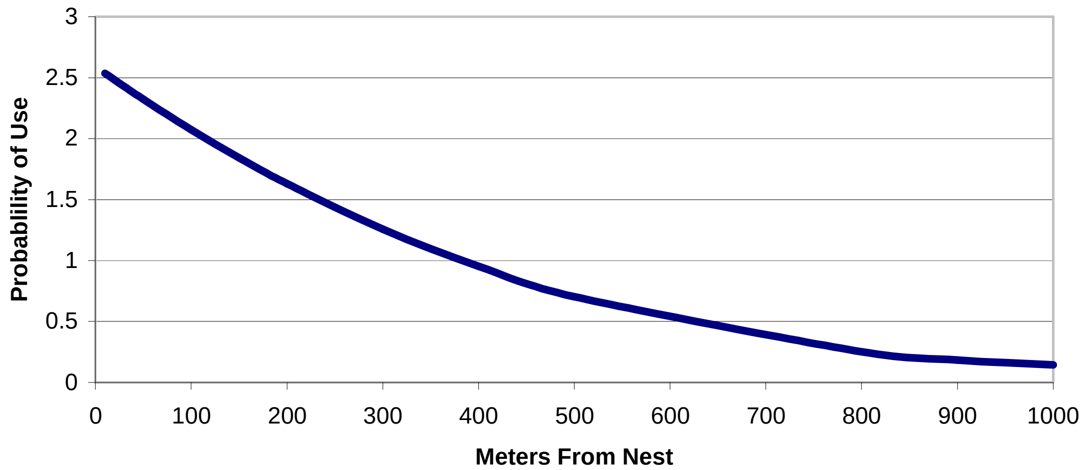

Figure 6.5. General relationship describing the non-linear decline in the probability of use with increasing distance from the site center or nest tree, at the Timbered Rock and Quartz Fires, Oregon, USA.

Within the fire owls selected NRF habitat with low/unburned severity burn, RF habitat with moderate severity burn, and used areas lower in elevation and closer to perennial streams (Table 6.7). NRF habitat with moderate severity burn occurred in several top models, and several owls demonstrated selection, but the relationship was never significant and most owls used this habitat in proportion to its availability within the home range (Appendix L). Outside the fire, spotted owls selected areas lower in elevation and NRF habitat with low/unburned severity burn. Use of NRF habitat with a low/unburned severity declined with increased distance from site center. Owls outside the fire lacked a clear association with hard edges, as the variable was rarely significant.

Seasonal Habitat Selection

Breeding and non-breeding season habitat selection models were analyzed but provided little additional information that was not included in year-round models (see Appendices Q - R for relationships of individual parameters). Breeding season models were the least complex and included the least amount of variables, but overall patterns were similar to year-round models. Non-breeding season models tended to be the most complex and contained similar variables as year-round habitat selection models. Variables that indicated selection of NRF habitat with a moderate severity burn and selection of areas closer to hard edges appeared more frequently in the non-breeding season than year-round models. This indicated these variables play an important role in post-fire habitat selection of spotted owls.

Comparison of High and Low Use Plots

The best logistic regression model that described differences in stand level habitat features of high and low use plots included the number of live conifers < 15 cm DBH, shrub-cover > 2 m in height, volume of down woody debris, and the basal area of the dead trees within the plot. The number of live conifers < 15 cm DBH was greater in high use plots (β = 0.09, 95% C.I. = 0.00 – 0.18). High use plots also had greater amounts of shrub-cover > 2 m in height (β = 0.36, 95% C.I. = 0.01 – 0.71). Down woody debris was less on high use plots, but this relationship was marginally significant (β = -0.01, 95% C.I. = -0.01 – 0.00). The basal area of dead trees was lower on high use plots, which was also marginally significant (β = -1.91, 95% C.I. = -3.86 – 0.05). These results indicated that high use areas had greater understory complexity and received less severe burns in the understory than similar stands that were used infrequently within the home range.

DISCUSSION

Nesting, Roosting and Foraging Habitat

Habitat selection results generated from my study followed results of previous research, but provided new results on important habitats for spotted owls after fires. Regardless of scale or residence within or outside the fire, spotted owls demonstrated a strong selection for NRF habitat with a low/unburned fire severity and used this habitat in greater proportion than its availability (Appendix L), which followed my initial prediction. Spotted owls have consistently selected the oldest and most structurally diverse forests as preferred habitat, throughout most of their range (Forsman et al. 1984, 2005, Thomas et al. 1990, Carey et al. 1992, Glenn et al. 2004). Following wildfire, large amounts of owl habitat was altered or destroyed, so it is understandable that owls select the highest quality habitat with the lowest level of fire severity. Within NRF habitat with a low/unburned severity, owls selected areas with the least amount of fire damage, as high use areas had decreased fire severity and increased structural diversity following wildfire compared to similar stand types within the home range. NRF habitat that had little to no overstory canopy mortality was clearly the most important habitat for spotted owls following wildfire.

NRF habitat with a moderate severity burn also was important to spotted owls throughout the landscape, as owls inside the fire selected this habitat, which was not initially predicted. At the home range scale, use of this habitat was usually determined as a function of distance from the nesting center. When an interaction between distance from nesting center and moderately burned NRF habitat was modeled, the use of this habitat was somewhat clarified. In general, owls selected moderately burned NRF habitat that was close to the nesting center, but the probability of use declined with increased distance from the nesting center. Furthermore, this relationship indicated this habitat was selected near the nesting center and used more frequently than other habitats as distance from site center increased. Overall, relative use of this habitat was low compared to NRF habitat with low severity burn, which provides additional evidence of the importance of older forests with little fire damage to spotted owls. Moderately burned NRF habitat was also used in roughly equal proportion to its availability by individual owls (Appendix L), which further suggests some benefit of this habitat to spotted owls.

Wildfire degraded the overall quality of NRF habitat through the destruction of a multilayered canopy, removal of coarse woody debris, and opening of the canopy, but many desirable habitat features likely still existed (see description of spotted owl habitat in Thomas et al. 1990:164), which made moderately burned NRF habitat of use to spotted owls. The suitability of this habitat will increase over time as mid-canopy trees begin to fill in gaps in the canopy, snags are created by wildfire, which become down woody debris, and the understory vegetation recovers creating a complex vertical structure. In addition, moderately burned stands likely have decreased risk of stand replacement in the future due to the removal of ladder fuels (Agee 1993). Moderately burned NRF habitat provided a beneficial habitat to spotted owls and will likely provide areas of high quality habitat over time as structural complexity is restored.

NRF habitat with high severity burn was selected by spotted owls over early seral forests in this study at a landscape scale and used in equal proportion to its availability within individual home ranges (Appendix L). This was a surprising result, which I did not predict because high severity burns were previously thought of as unsuitable owl habitat, as it no longer provided sufficient overstory canopy cover, structural complexity, and downed wood (Mills et al. 1993, Buchanan et al. 1995, North et al. 1999, Herter et al. 2002). However, it should not be implied that spotted owls can persist in areas of complete overstory stand removal. Relative use of NRF habitat with high severity burn was low compared to other habitats and likely suggests that these stands do not provide high quality habitat for spotted owls. Furthermore, there is likely a minimum level of high quality habitat necessary to allow occupancy of spotted owls in a territory following wildfire (see Chapter 3). While, these areas of stand replacement may not provide high quality habitat, they likely provided some benefit to owls following wildfire because owls did make use of these stands. I hypothesize that high severity burns in NRF habitat which created early seral stands may be used by owls because they may provide increased prey abundance (Sakai and Noon 1993, Carey and Peeler 1995, Ward et al. 1998), but I was unable to test this hypothesis. Furthermore, large dead trees created by wildfire are likely to serve as “legacy structures”, and provide coarse woody debris and snags for future late-successional forests (Franklin et al. 2000, Lindenmayer and Franklin 2002, Noss et al. 2006), potentially making these stands important to creation of spotted owl habitat in the future. In addition, early seral forests created by disturbance events that are not altered by timber harvest are extremely rare (Noss et al. 2006) and support some of the highest levels of biodiversity (Lindenmayer and Franklin 2002). Therefore, the potential ecological benefits of large standing dead trees should be weighed against social and economic objectives when considering land management activities.

Roosting and Foraging Habitat

RF habitats were used differently depending on the level of fire severity within the stand. Regardless of scale, spotted owls used high severity burns within RF habitat similar to early seral forests and typically less frequently than expected within the home range, indicating these areas are likely poor habitat for spotted owls. In contrast, moderately burned RF habitat was selected by some owls, which I did not initially predict. While some owls selected this habitat, relative use of this cover type across owls was low and suggested that this habitat does not provide a large benefit to all owls. Owls that had greater amounts of this habitat available within their home range frequently demonstrated selection for this cover type, which suggests that owls may use this habitat frequently if it is available in large amounts within their territory. In general, most owls used this habitat in equal proportion to its availability within the home range (Appendix L).

Several hypotheses exist to help explain why some owls selected RF with moderate severity burn. Spotted owls may have selected these stands because they were opened by wildfire allowing owls to efficiently forage. Furthermore, the heterogeneity created by wildfire likely increased small mammal abundance, similar to the effects of heterogeneous thinning of young stands (Carey 2001). Spotted owls have been shown to disproportionately forage in habitats that have high levels of prey abundance (Carey et al. 1992, Carey and Peeler 1995, Zabel et al. 1995). Furthermore, these stands may have increased benefits to spotted owls over time as residual trees may have increased growth rates from decreased competition (McComb et al. 1993, Tappiener et al. 1997, DeBell et al. 1997). While these hypotheses may help explain why owls selected these stands, I did not test these hypotheses and the reason for selection is not known.

In contrast, RF habitat with low/unburned severities was used in a similar manner as early seral forests, although many owls used this habitat in equal proportion to its availability (Appendix L) and owls outside the fire boundary selected this habitat over early seral stands within the unburned landscape. This result is somewhat surprising because spotted owls will make use of younger forests (Carey and Peeler 1995, Folliard et al. 2000, Glenn et al. 2004). Many owls in this study used young forests less frequently than available, but relative use was fairly high compared to other habitats, suggesting some benefit of this habitat to spotted owls. I hypothesize that some spotted owls may have used these areas less frequently than expected because these stands may be too densely stocked to allow efficient foraging. In addition, woodrats are the primary prey species of spotted owls throughout southwest Oregon (Solis and Gutiérrez 1990, Ward et al. 1998) and dusky footed woodrats (*Neotoma fucipes*) are typically found in lowest abundance within intermediate seral stages (Sakai and Noon 1993). Use of these stands may be restricted due to lack of prey (Carey and Johnson 1995), but inference on these hypotheses is beyond the scope of my study.

Salvage Logging

While my analysis suggested that owls used salvage logged stands in a similar manner as early seral forests, further evaluation revealed that 60% of owl locations were within salvaged areas associated with patches of wildlife "leave" trees, riparian buffers, or stands of thinned trees. This suggested that owls were not using salvage areas that were clear-cut, but used areas where remnant structures remained following harvest. In previous research, spotted owls have been observed using remnant structures left during timber harvest operations (Mieman et al. 2003), as these areas likely provide foraging opportunities. Areas receiving large scale clear-cut logging were rarely used by spotted owls, in other research (Forsman et al. 1984) and in this study. Furthermore, salvage logged areas tended to be used less frequently than available throughout individual home ranges (Appendix L). Therefore, clear-cut salvage logging is likely detrimental to spotted owls because it reduced the quality of habitat available for foraging following wildfire. Inferences to the impacts of additional salvage techniques such as thinning with retention of green trees on spotted owl habitat use is limited, because areas within the boundaries of the telemetry study were primarily clear-cut salvage logged.

Utilization of Unburned Habitat

Spotted owls with territories located immediately adjacent to the fire that had moderate and high severity burns, and salvage logged areas available to them avoided these habitats and had < 5% of their locations fall within the boundaries of the fire. Furthermore, owls that ventured into the fire were typically individuals that were displaced by fire and periodically visited their old territory. This suggested that when given the opportunity, owls focused their activities in unburned habitat. Utilization of unburned habitats was further demonstrated by several owls with territories inside the fire frequently traveling long distances to forage in unburned habitat. This finding supported my initial prediction that spotted owls would focus activities in the oldest forest stands with the least amount of fire damage, which was forest stands with no fire damage.

Even at low severities, forest fires are likely to reduce the vertical structure within forest stands (Agee 1993), which may reduce the quality of the habitat for spotted owls. Therefore, it was not surprising that owls utilized areas of unburned habitat when provided the opportunity. Furthermore, owls outside the fire avoided moderate and high severity burns, while some owls inside the fire selected these habitats. This suggested that owls will simply make use of the best available habitat. Spotted owls will persist on the site as long as enough suitable habitat remaining after wildfire (see Chapter 3 of this thesis). If there is not enough suitable habitat available, owls will emigrate out of the fire to a neighboring site that is unoccupied, or they will likely have decreased survival rates (see Chapter 4 of this thesis). Furthermore, these relationships suggest that wildfire degraded the quality of spotted owl habitat in the short term, but fire events are likely essential to the long term conservation of owls in dry forests, as low severity fires reduce the risk of stand-replacing fires. This creates a dilemma for land managers because active fire suppression is still currently practiced, therefore natural fire is likely not an option to reduce fire risks. In addition, there are prohibitive costs associated with the treatment of large areas to reduce fire risk and these techniques likely can not be applied to sufficient areas to be effective. Furthermore, the management of dry forest ecosystems is a controversial issue (Bestcha et al. 2004, Noss et al. 2006) and it will be difficult to reach a consensus on appropriate methods to reduce fire risks while limiting detrimental impacts to spotted owls and other species associated with older forests.

Use of Habitats Near the Site Center

The majority of spotted owls in this study showed a non-linear decline in the probability of using habitats further from the nesting center. This relationship has been suggested in other spotted owl studies (Glenn el al. 2004) and was expected for this central-place forager (Rosenberg and McKelvey 1999). Including a distance from nesting center function in habitat models likely helped clarify the relationship between habitat selection and habitat availability. The exclusion of the distance function would likely have led to habitats close to the site center being selected, while distant habitats would be avoided. Spotted owls tend to have high proportions of high quality habitat near the nesting center (Ripple et al. 1991, 1997, Lemkuhl and Raphael 1993, Swindle et al. 1999), so I likely would have only found selection for high quality habitats near the site center without the distance from nesting center function. Furthermore, the relationship of owls having a higher probability of using areas near the nesting center indicates the overall importance of habitats in the core area. Core areas were typically comprised of NRF habitat with a low/unburned severity. Moreover, fire severities tended to be lower and understory complexity tended to be higher in core areas than similar habitats throughout the home range. This provided evidence that older forests with the least amount of fire damage are most important to spotted owls following wildfire.

Abiotic Factors Influencing Habitat Selection

Spotted owl habitat selection was also influenced by other factors. Some owls selected areas closer to hard edges than available within their home range, which supported my initial prediction. Spotted owls may prefer to forage on habitat edges due to higher densities of some prey in early seral forests (Carey and Peeler 1995, Franklin et al. 2002), particularly woodrats in southwest Oregon and northwest California (Zabel et al. 1995, Ward et al. 1998). I had initially predicted that owls would select areas closer to perennial streams and use of elevations would be random, which was not the case in this study. Because owls selected areas closer to perennial streams, areas lower in elevation were also selected. Several hypotheses exist to explain the disproportionate use of areas lower in elevation and closer to perennial streams, including thermoregulatory constraints for roosting (Barrows 1981, Forsman et al. 1984), increased prey abundance (Carey et al. 1999), decreased fire severity in riparian areas (Reeves et al. 2006) allowing retention of large trees and structural complexity, although I was unable to test these hypotheses. It does not appear that high quality habitats are unequally distributed near riparian areas (Appendix S) and owls are likely using areas closer to perennial streams due to the previous hypotheses or other unknown factors.

Spotted owls in this study were often found to use areas closer to roads than at random, especially at a landscape scale. The difference between owl locations and random locations was likely not biologically significant, because telemetry locations were predominately on Bureau of Land Management and private landownership with high road densities. In contrast, random points were frequently located on Forest Service (FS) ownership, which had lower road densities and were infrequently used by radio-marked owls. Consequently, the large difference was likely related to the high road densities near nesting centers in relation to the overall low density of roads throughout the study area. Furthermore, the use areas closer to roads rarely appeared in home range scale selection models. Home ranges in this study rarely included FS managed lands and therefore the relationship between roads and owl locations is likely not biologically relevant, which supported my initial prediction. The potential also existed for locations to be closer to roads because telemetry locations were gathered from roads. The accuracy of locations generally declined with increasing distance from the observer and quality bearings often could not be obtained in areas with low road densities.

CHAPTER 7

SUMMARY AND MANAGEMENT RECOMMENDATIONS

Darren A. Clark

SUMMARY

Wildfire was the leading cause of habitat loss on lands administered by the Federal Government from 1994 – 2003 within the range of the northern spotted owl (*Strix occidentalis caurina*) (Davis and Lint 2005), and the sustainability of spotted owl populations in fire prone ecosystems has been questioned (Spies et al. 2006). Little is known about occupancy, survival, reproduction and habitat selection of spotted owls in recently burned landscapes. From 2001 and 2002, 3 large fires (Biscuit, Quartz and Timbered Rock) occurred in southwestern Oregon and provided the opportunity to investigate the impacts of wildfire on spotted owls. In 2003 – 2006, I used radio-telemetry and demographic surveys to describe habitat selection, home range size, occupancy, productivity and survival of spotted owls within and adjacent to the burned areas.

Occupancy of spotted owl territories following the Timbered Rock Fire declined much more rapidly than unburned owl territories in the South Cascades Demography Area. The rapid decline in occupancy following the Timbered Rock Fire was driven by elevated extinction rates, which likely reflected increased emigration and decreased survival. Wildfire and subsequent salvage logging on private timberlands were likely responsible for the elevated extinction rates following the Timbered Rock Fire, although I did not examine the impacts of wildfire and salvage separately in this analysis.

Occupancy rates at the Biscuit, Quartz and Timbered Rock Fires all declined from 2003 – 2006. Initial occupancy rates were positively associated with increased amounts of roosting and foraging habitat with low severity burns within owl core areas ($\beta = 0.08$, 95% C.I. = -0.02 – 0.17) and suggested that some amount of habitat heterogeneity within

the core area benefited initial occupancy. Furthermore, initial occupancy was negatively associated with increased amounts of hard edge within the core area (β = -0.33, 95% C.I. = -0.77 – 0.10), which suggested that habitat fragmentation negatively impacted initial occupancy following wildfire.

Extinction was the most critical factor influencing declines in post-fire occupancy at the 3 fires. Extinction rates increased in a curvilinear manner as the amount of unsuitable habitat within the core area increased (β = 2.15, 95% C.I. = 0.25 – 4.05), suggesting that high severity fire and pre- and post-fire timber harvest negatively impacted owl occupancy. Furthermore, extinction was positively associated with hard edge (β = 0.20, 95% C.I. = -0.01 – 0.41), which suggested that occupancy was negatively impacted by habitat fragmentation from salvage logging and high severity fire.

Post-fire colonization was positively correlated with the amount of nesting, roosting and foraging habitat that received a low severity burn within the core (β = 0.08, 95% C.I. = 0.02 – 0.15), which supported the premise that spotted owls are dependent upon older forests (Forsman et al. 1984, Thomas et al. 1990). Colonization also was positively associated with high severity fire within the home range in a curvilinear manner (β = 2.30, 95% C.I. = 0.21 – 4.39). While this result is counter-intuitive, occupancy is dependent on a site being unoccupied in the previous year (MacKenzie et al. 2003). High severity fire contributed to sites becoming unoccupied (i.e. extinct); therefore, sites that had large amounts of high severity fire were available for colonization.

Productivity in burned landscapes at the Biscuit, Quartz and Timbered Rock Fires was not significantly different than unburned landscapes at the South Cascades

Demography Area, although I likely lacked sufficient statistical power to detect significant differences. This was similar to the findings of previous studies that found wildfire had little impact on spotted owl reproduction (Bond et al. 2002, Jenness et al. 2004). My results suggested that spotted owls with territories in burned landscapes produce young at a similar rate to owls in unburned landscapes. While owl pairs inside fires likely produced young at a similar rate to owls outside fires, overall reproductive output declined following wildfire. This is because the total number of owl pairs following wildfire declined and therefore less total young were produced each year, which indicated a negative impact of fire on spotted owl reproduction.

Annual survival rates of spotted owls that occupied territories in burned landscapes or that were displaced by wildfire were lower (0.64, 95% C.I. = 0.37 – 0.84) than those in unburned territories at the South Cascades Demography Area (0.85, 95% C.I. = 0.83 – 0.88) (Anthony et al. 2006), and owls in unburned habitat in this study (1.00, 95% C.I. = 1.00 – 1.00). Similarly, survival rates over the entire course of this study (19 months) for owls inside or displaced by fire were lower (0.33, 95% C.I. = 0.12 – 0.64) than for owls outside the fire (1.00, 95% C.I. = 1.00 – 1.00). These results indicated that wildfire and salvage logging of burned areas likely impacted survival rates of spotted owls negatively. These 2 factors decreased the amount of suitable habitat available to owls and increased the amount of unsuitable habitat, which has a negative impact on survival rates of spotted owls (Franklin et al. 2000, Olson et al. 2004, Blakesley et al. 2005, Dugger et al. 2005). I was unable to estimate the impacts of wildfire and salvage logging separately on spotted owl survival because they were highly interrelated and I lacked sufficient data to model these effects separately. In addition, low and moderate severity fires may negatively impact survival rates through the removal of coarse woody debris and understory vegetation, which may degrade spotted owl habitat and potentially decrease prey abundance.

Annual home ranges of spotted owls prior to wildfire at Timbered Rock in the Miller Mountain Telemetry Study (Anthony and Wagner 1998) were 248 ha (95% C.I. = 82 – 491) smaller on average than home ranges of spotted owls in my study ($t = -2.85$, $df = 32$, $p < 0.01$). This suggested that wildfire and subsequent salvage logging caused spotted owls to increase their home ranges. Given that home ranges increased after fire, I expected that home ranges of owls outside the fire would be smaller than owls inside the fire in this study. This was not the case as annual and seasonal ranges of both groups did not differ in size.

The habitat variable that best described home range size in this study was the length of hard edge within the home range. Annual home ranges increased as the amount of hard edge increased ($\beta = 30.71$, $SE = 2.65$, $p < 0.01$), and a similar relationship was observed for breeding and non-breeding season home ranges. Hard edge was defined as the interface between unsuitable and suitable habitat and represented the degree of habitat fragmentation. This suggested that owls increase home ranges in response to increased fragmentation. This relationship may have explained why home range size did not differ between owls inside and outside the fire. Several owl pairs outside the fire had the greatest amount of edge within their territories, and this contributed to their large home ranges. I did not find that the amount of older forest within the home range influenced home range size as in other studies (Carey et al. 1992, Glenn et al. 2004, Hamer et al. 2007), but I did observe a negative correlation ($r = -0.44$, $p = 0.04$) between the amounts of older forest and hard edge. This suggested that as the amount of older forest decreased, the amount of hard edge increased, and potentially explained the larger home ranges observed in my study.

Spotted owls selected nesting, roosting and foraging habitat with low severity burn at a landscape or home range scale. This was expected because previous research has documented disproportional use of the oldest and most structurally diverse habitats by spotted owls (Forsman et al. 1984, see review in Thomas et al. 1990, Carey et al. 1992, Glenn et al. 2004, Forsman et al. 2005, Hamer et al. 2007). Furthermore, spotted owls disproportionately used habitats that had the least amount of fire damage and increased structural diversity within nesting, roosting and foraging habitat with low severity burn.

Nesting, roosting and foraging habitat with moderate or high severity burns was also selected by spotted owls at a landscape scale and used in proportion to availability within individual home ranges. Moderately burned older forests were likely temporarily degraded by wildfire because the fire likely removed many of the structural forest components that spotted owls are associated with (Thomas et al. 1990). But many desirable habitat features must exist following wildfire for spotted owls to select this habitat. Spotted owl habitat with high severity burn was previously thought of as unsuitable habitat because it no longer provided sufficient canopy cover, structural complexity, and downed wood (Mills et al. 1993, Buchanan et al. 1995, North et al. 1999, Herter et al. 2002). Older forest with a high severity burn likely provided some benefit to spotted owls because they were observed using it in my study. Therefore, this habitat should be given some level of protection following wildfire if the conservation of spotted owls is the primary objective during post-fire land management.

Spotted owls used roosting and foraging habitat with low or high severity burn in a similar manner to early seral forests. Use of roosting and foraging habitat with high severity burn was very low suggesting that this cover type was poor habitat for spotted owls. Roosting and foraging habitat with low severity burn was not selected, but use was relatively frequent and typically in proportion to availability within the home range, which suggested this habitat may have some benefit to spotted owls. In contrast, roosting and foraging habitat that received a moderate severity burn was selected by some owls, but was used in a relatively low amount by all owls. I hypothesize that this habitat was selected by some owls because it was likely opened by wildfire, which allowed owls to more efficiently forage, or these stands may have increased prey abundance due to the heterogeneous thinning created by wildfire (Carey 2001). Spotted owls used areas that were salvage logged in a similar manner to early seral forests and typically less frequently than available throughout individual home ranges. My results suggested that clear-cut salvage logging reduced the quality of habitat for spotted owls and provided no benefit to spotted owl habitat use.

Some spotted owls selected areas closer to hard edges than at random, which has been documented in previous research (Zabel et al. 1995). This phenomenon has been hypothesized to occur because of increased prey densities in early-seral forests (Carey and Peeler 1995, Franklin et al. 2003), but inference on this hypothesis was beyond the scope of my study. Furthermore, other studies have not found a strong selection for edge habitats (Glenn et al. 2004, Forsman et al. 2005, Hamer et al. 2007). In addition, spotted owls selected areas lower in elevation and closer to perennial streams. Owls may use these areas disproportionately due to thermoregulatory benefits (Barrows 1981, Forsman et al. 1984), increased prey abundance (Carey et al. 1999), or decreased fire severities in riparian areas (Reeves et al. 2006).

My results support the hypothesis that wildfire was detrimental to spotted owls by decreasing survival and occupancy rates over the short-term. Further research is needed to investigate the impacts of high severity wildfire and salvage logging on survival rates of spotted owls because I was unable to separate these factors. Furthermore, spotted owl occupancy rates should be monitored long-term to determine if they increase after some time period. Developing an understanding of the long-term impacts on spotted owl populations is needed to determine if wildfire reduces the sustainability of owl populations over time. It also remains to be seen if post-fire land management activities are compatible with the long-term conservation of spotted owls in burned landscapes. In addition, further investigation is needed to determine the ability of land management activities to reduce fire risk in dry forest ecosystems while still providing spotted owl habitat. Development of post-fire land management activities and strategies to reduce fire risks in dry forest ecosystems, while limiting impacts to spotted owls and other species associated with older forests, will be a major challenge facing land managers in the future.

MANAGEMENT RECOMMENDATIONS

Given that spotted owls in this study had decreased survival and occupancy following wildfire, it is apparent that wildfire and salvage logging collectively had negative impacts on spotted owls in the short-term (i.e. 2 – 5 years post-fire). Therefore, the negative impacts of wildfire on spotted owls should be incorporated into conservation plans or management techniques that reduce the risk of stand-replacing wildfire should be developed. Future research is needed to investigate the impacts of low intensity prescribed fire and mechanical thinning on spotted owls to determine prescriptions that are effective at reducing fire risk, while limiting detrimental impacts to spotted owl habitat and prey. Based on the results of my research, I predict that low intensity prescribed fire may be used to help reduce fire risk in dry forest ecosystems occupied by spotted owls. Low intensity prescribed fires that affect the forest floor and only cause mortality to understory trees will likely not have negative impacts on spotted owls or their prey over the long-term. When implementing prescribed burning within a spotted owl territory, activities should be restricted to a small portion of a nesting territory within a short-time frame (e.g. 5 year period) to reduce the short-term impacts of prescribed fire on spotted owls and their prey. Recommendations on the development of mechanical thinning treatments in spotted owl habitat are beyond the scope of my study and future research is needed to investigate the impacts of thinning treatments on spotted owls. Development of these prescriptions will be a major challenge facing wildlife and land managers, because the vegetation structure associated with quality spotted owl habitat is often in exact opposition to the goal of reducing wide spread fire risk. The management of dry forest ecosystems is highly contentious (Beschta et al. 2004, Noss et al. 2006) and will likely complicate the development of prescriptions to reduce fire risk. Furthermore, the reduction of fire risk across large areas will be extremely expensive and may be difficult to implement due to limited monetary resources.

Post-fire home ranges of spotted owls in this study were larger than normally documented in this region and suggested that spotted owls utilized a larger area following wildfire. Home range estimates from this project may be used to determine the minimum amount of habitat that spotted owls use after wildfire in dry forest ecosystems within the Klamath Province and the west slope of the southern Oregon Cascades. Based on the average home range size of 661 ha observed in this study, I suggest that the minimum territory size for spotted owls in post-fire landscapes in southwest Oregon be defined by a circle with a 1.5 km radius centered on a nest tree/site center. This territory size can be used to identify and protect owl habitat during post-fire land management activities.

Spotted owls in this study selected nesting, roosting and foraging habitats with a low or moderate severity burn. Furthermore, owl territories that had greater amounts of nesting, roosting and foraging habitat with a low severity burn were more likely to be colonized by spotted owls. Therefore, I recommend these habitats be protected on public lands throughout the landscape during post-fire land management activities to encourage habitat use and colonization by spotted owls. Furthermore, spotted owls selected nesting, roosting and foraging habitat that received a high severity burn. On public lands where the conservation of spotted owls is a priority, I recommend this habitat be protected within 1.5 km of occupied spotted owl territories and at unoccupied territories where sufficient habitat remains to promote colonization by spotted owls in the future.

Post-fire land management incorporates social, economic and ecological objectives that are often in direct opposition with each other. My results suggested that clear-cut salvage logging is not an appropriate management activity in areas where the conservation of spotted owls is the primary objective. It remains to be seen if other salvage logging prescriptions that incorporate thinning are less detrimental to spotted owls than clear-cut salvage. Therefore, I recommend that no clear-cut salvage occurs within 1.5 km of occupied spotted owl nesting centers on publicly administered lands where the conservation of spotted owls is the primary objective. If salvage logging is an important component of additional management objectives, thinning with retention of green trees and snags would be the least detrimental activity to spotted owls. In addition, patches of leave trees and riparian buffers should be left to encourage use by spotted owls. Furthermore, if salvage logging is deemed to be an appropriate land management activity, I recommend caution is taken to ensure that salvage logging prescriptions have minimal impacts to spotted owls, their habitat and prey.

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APPENDICES

Appendix A. Error matrix comparing classified data points from post-fire habitat maps to reference data collected in the field at the Biscuit, Quartz and Timbered Rock Fires, Oregon, USA.

Biscuit Fire

Classified Data	Reference Data									Total
	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage	
Non	6	1	0	0	0	0	0	0	0	7
Early	1	4	0	0	0	0	0	0	0	5
RFLow	0	2	4	1	0	0	1	0	0	8
RFMod	0	0	1	4	2	1	0	0	0	8
RFHigh	0	0	0	0	4	0	0	1	0	5
NRFLow	0	0	2	0	0	11	0	0	0	13
NRFMod	0	0	0	0	0	2	4	1	0	7
NRFHigh	0	0	0	0	2	0	1	4	0	7
Salvage	0	0	0	0	0	0	0	1	3	4
Total	7	7	7	5	8	14	6	7	3	64

Quartz Fire

Classified Data	Reference Data									Total
	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage	
Non	0	0	0	0	0	0	0	0	0	0
Early	0	10	0	1	0	0	0	0	0	11
RFLow	0	0	4	1	0	1	0	0	0	6
RFMod	0	1	0	0	1	0	0	0	0	2
RFHigh	0	0	0	0	2	0	0	0	0	2
NRFLow	0	0	2	1	0	11	0	0	0	14
NRFMod	0	0	0	0	0	1	5	1	0	7
NRFHigh	0	0	0	2	0	0	3	8	0	13
Salvage	0	0	0	0	0	0	0	0	4	4
Total	0	11	6	5	3	13	8	9	4	59

Appendix A. Table continued from previous page…

Timbered Rock Fire										
	Reference Data									
Classified Data	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage	Total
Non	2	0	0	0	0	0	0	0	0	2
Early	0	6	2	1	0	2	0	0	0	11
RFLow	0	0	4	1	0	2	0	0	0	7
RFMod	0	0	0	2	0	0	0	0	0	2
RFHigh	0	2	0	0	3	0	0	0	0	5
NRFLow	0	2	1	0	0	14	1	0	0	18
NRFMod	0	1	0	0	0	1	6	1	0	9
NRFHigh	0	0	0	0	1	0	0	5	0	6
Salvage	0	0	1	0	0	0	2	1	5	9
Total	2	11	8	4	4	19	9	7	5	69

Appendix B. Historic owl territories surveyed at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon to assess post-fire occupancy and productivity.

Site Name	Landowner	Years Surveyed
Biscuit Fire (*n* = 9)		
Days Gulch	USFS	2003 - 2006
East Chief Creek	USFS	2003 - 2006
Mikes Gulch	USFS	2003 - 2006
North Sixmile Creek	USFS	2003 - 2006
Pine Creek Camp	USFS	2003 - 2006
Red Dog Creek	USFS	2003 - 2006
Silver Falls	USFS	2003 - 2006
Sourgrass	BLM	2003 - 2006
Squaw Creek	USFS	2003 - 2006
Quartz Fire (*n* = 9)		
Dutchman South	USFS	2002 - 2006
Garvin Gulch	USFS	2002 - 2006
Glade Creek	USFS	2002 - 2006
Happy Dutch	BLM	2002 - 2006
Hendricks Creek	Private	2002 - 2006
Lick Gulch	BLM	2002 - 2006
New Site	USFS	2002 - 2006
Quartz Gulch	BLM	2002 - 2006
Woodpecker Springs	USFS	2002 - 2006
Timbered Rock Fire (*n* = 22)		
Alco Creek	BLM	2003 - 2006
Alco Ridge	BLM	2003 - 2006
Alco Rock	BLM	2003 - 2006
Alco Rock West	BLM	2003 - 2006
Elkhorn	BLM	2003 - 2006
Flat Creek	BLM	2003 - 2006
Flat Creek Divide	BLM	2003 - 2006
Gobblers East	BLM	2003 - 2006
Gobblers Knob	BLM	2003 - 2006
Hawk Creek	USFS/BLM	2003 - 2006
Lower Pelt Creek	USFS	2003 - 2006
Lower Timber Creek	BLM	2003 - 2006
Middle Creek	BLM	2003 - 2006
Miller Mountain	BLM	2003 - 2006
Pelt Creek	USFS	2003 - 2006
Ragsdale	BLM	2003 - 2006
Shell Rock	BLM	2003 - 2006
Timbered Rock	BLM	2003 - 2006
Upper Elkhorn Creek	USFS	2003 - 2006
Upper Pelt Creek	USFS	2003 - 2006
Upper Timber Creek	BLM	2003 - 2006
West Branch Elk Creek	BLM	2003 - 2006

Appendix C. Percent of each habitat cover type within a circle with a 2,230 m or 730 m radius of the historic northern spotted owl site center at the Biscuit, Quartz and Timbered Rock Fires.

2,230m Radius Circle									
	Cover Type								
Site Name	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Quartz Fire									
Dutchman South	0.0	18.0	3.8	0.0	0.0	46.7	3.2	20.5	7.8
Garvin Gulch	2.3	25.9	14.3	0.5	0.1	36.7	2.6	9.5	8.1
Glade Creek	1.5	14.7	5.8	1.3	1.3	29.0	5.4	17.4	23.7
Happy Dutch	1.5	22.0	9.1	3.8	2.1	31.2	6.6	6.0	17.7
Hendricks Creek	2.4	24.2	13.4	0.1	0.1	47.9	1.6	1.4	9.0
Lick Gulch	1.2	22.3	13.5	3.3	1.5	38.6	7.8	5.0	6.8
New Site	2.0	22.1	7.3	3.2	2.1	23.6	6.7	7.6	25.5
Quartz Gulch	2.6	14.6	15.0	4.4	2.2	27.1	9.1	6.3	18.8
Woodpecker Springs	0.7	15.3	21.5	1.4	1.9	25.1	5.0	14.8	14.2
Yale Creek	1.2	22.5	41.0	0.0	0.4	34.8	0.1	0.1	0.0
Biscuit Fire									
East Chief Creek	0.2	11.0	12.5	3.3	1.8	53.9	7.0	7.0	3.3
Mikes Gulch	33.8	3.7	5.8	2.8	8.5	8.8	12.2	23.9	0.5
Days Gulch	31.8	9.6	13.5	8.4	6.4	11.0	5.0	8.5	5.8
North Sixmile Creek	4.3	8.3	32.9	10.4	1.8	35.4	4.1	2.9	0.0
Pine Creek Camp	4.5	7.4	25.9	5.1	8.7	21.6	6.9	20.0	0.0
Red Dog Creek	17.7	14.7	17.8	2.6	1.0	30.2	3.0	9.0	3.9
Silver Falls	8.0	5.4	15.3	13.4	13.6	16.7	9.7	17.9	0.0
Sourgrass	1.3	18.8	17.9	13.4	5.6	30.6	6.6	4.9	1.0
Squaw Creek	64.2	0.1	2.0	2.9	1.3	13.2	5.7	10.7	0.0
Timbered Rock Fire									
Alco Creek	7.1	32.5	10.1	4.6	1.2	9.0	2.4	1.4	31.8
Alco Ridge	0.0	24.9	10.4	3.4	0.6	16.4	4.3	1.9	38.2
Alco Rock	0.0	31.1	1.9	4.9	5.2	16.8	7.7	7.4	25.1
Alco Rock West	0.0	44.5	10.9	1.8	0.7	24.8	4.8	3.9	8.7
Elkhorn Creek	0.4	21.7	8.1	1.7	2.4	39.2	11.8	5.0	9.6
Flat Creek Divide	0.0	30.1	3.4	4.0	5.3	8.0	9.3	5.6	34.3
Flat Creek	0.0	12.3	24.0	0.6	2.8	41.8	9.1	5.9	3.6

Appendix C. Table continued from previous page…

2,230m Radius Circle

Site Name	Cover Type								
	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Gobblers East	0.4	29.3	5.9	3.2	2.8	15.5	11.0	7.0	24.9
Gobblers Knob	0.0	33.9	4.8	1.6	1.5	25.0	10.4	8.1	14.7
Hawk Creek	0.0	27.6	3.4	0.9	3.1	43.5	9.0	10.1	2.3
Lower Pelt Creek	0.0	17.7	4.5	0.1	0.0	68.9	7.0	1.8	0.0
Lower Timber Creek	1.0	27.4	14.5	3.0	3.9	24.4	7.9	3.5	14.4
Middle Creek	0.0	35.2	2.4	7.9	3.6	7.1	2.8	4.8	36.2
Miller Mountain	4.2	22.9	9.9	7.1	3.9	10.5	5.0	2.8	33.7
Pelt Creek	0.0	27.2	6.2	0.8	1.6	49.9	7.6	6.6	0.0
Ragsdale	0.0	33.7	4.6	2.6	5.8	28.5	8.2	7.6	9.1
Shell Rock	0.1	24.2	4.8	8.5	5.6	3.9	3.2	4.5	45.3
Timbered Rock	0.0	15.3	6.4	3.0	6.5	32.1	11.9	19.0	5.7
Upper Elkhorn Creek	0.0	26.1	14.1	0.1	0.0	58.1	1.6	0.0	0.0
Upper Pelt Creek	0.0	32.1	5.3	0.5	2.8	42.2	6.0	11.0	0.0
Upper Timber Creek	0.0	28.9	4.8	3.5	5.6	26.4	8.2	20.2	2.5
West Branch Elk Creek	0.0	20.4	10.2	5.3	1.0	26.7	3.8	1.9	30.6

730m Radius Circle

Site Name	Cover Type								
	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Quartz Fire									
Dutchman South	0.0	27.9	17.5	0.0	0.0	54.6	0.0	0.0	0.0
Garvin Gulch	0.0	0.1	2.2	0.0	0.0	97.3	0.0	0.0	0.5
Glade Creek	0.0	12.9	4.3	4.3	0.0	18.9	15.2	25.2	19.2
Happy Dutch	0.9	43.4	0.1	4.1	0.0	18.8	11.6	17.0	4.1
Hendricks Creek	0.5	31.5	11.6	0.0	0.0	56.3	0.0	0.0	0.0
Lick Gulch	0.0	20.7	17.0	0.0	0.5	61.7	0.2	0.0	0.0
New Site	4.5	14.1	2.5	0.0	0.2	22.8	9.6	6.9	39.2
Quartz Gulch	4.3	13.9	3.3	15.0	10.4	6.9	16.2	24.5	5.6
Woodpecker Springs	0.0	0.0	9.0	0.4	0.0	24.6	9.3	41.9	14.7
Yale Creek	0.0	32.1	26.2	0.0	0.0	41.7	0.0	0.0	0.0

Appendix C. Table continued from previous page…

	730m Radius Circle								
	Cover Type								
Site Name	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Biscuit Fire									
East Chief Creek	0.0	0.0	15.3	0.2	0.0	75.7	5.6	3.1	0.0
Mikes Gulch	6.3	0.0	6.4	11.8	7.2	6.3	21.9	40.1	0.0
Days Gulch	0.8	5.1	32.0	2.1	6.5	44.9	4.3	4.2	0.0
North Sixmile Creek	0.0	11.3	35.0	1.3	0.0	51.7	0.8	0.0	0.0
Pine Creek Camp	5.0	3.1	24.4	3.7	3.1	43.7	3.3	13.6	0.0
Red Dog Creek	0.0	11.6	37.8	0.0	0.0	50.4	0.0	0.0	0.2
Silver Falls	0.0	3.5	19.4	2.3	7.6	51.6	2.0	13.5	0.0
Sourgrass	0.0	20.1	12.0	8.2	0.0	52.7	4.1	3.0	0.0
Squaw Creek	23.8	0.0	0.7	4.4	4.8	5.6	8.4	52.2	0.0
Timbered Rock Fire									
Alco Creek	0.7	48.9	4.2	2.6	0.9	0.9	2.8	0.0	39.0
Alco Ridge	0.0	11.9	5.8	6.4	0.0	1.2	4.9	0.0	69.9
Alco Rock	0.0	33.1	8.4	4.6	0.0	41.5	10.8	1.2	0.5
Alco Rock West	0.0	22.2	5.4	0.2	1.1	35.7	8.8	7.7	18.8
Elkhorn Creek	0.0	10.1	6.5	3.2	0.8	38.5	21.9	8.9	10.0
Flat Creek	0.0	14.1	1.1	6.6	3.6	24.2	10.9	6.4	33.3
Flat Creek Divide	0.0	3.6	12.8	2.6	6.7	46.2	20.8	7.1	0.0
Gobblers East	0.0	37.0	4.9	0.5	2.9	9.5	2.2	10.1	32.8
Gobblers Knob	0.0	38.1	2.4	4.2	1.5	14.1	16.0	7.0	16.7
Hawk Creek	0.0	3.2	0.0	0.0	0.0	69.4	16.0	11.4	0.0
Lower Pelt Creek	0.0	9.5	0.0	0.0	0.0	85.6	4.9	0.0	0.0
Lower Timber Creek	0.0	10.2	16.7	0.0	3.8	31.2	17.0	3.1	18.0
Middle Creek	0.0	33.3	7.2	14.4	0.0	7.9	2.0	0.0	35.2
Miller Mountain	0.0	32.5	16.9	8.2	1.0	8.9	6.3	3.2	23.0
Pelt Creek	0.0	56.4	0.2	1.2	0.0	41.2	1.0	0.0	0.0
Ragsdale	0.0	28.5	0.0	6.0	0.1	39.1	10.5	8.8	6.9
Shell Rock	0.0	24.8	0.0	6.5	4.6	0.0	0.0	17.7	46.4
Timbered Rock	0.0	9.2	0.7	0.0	0.9	15.7	19.1	52.1	2.3
Upper Elkhorn Creek	0.0	16.8	16.3	0.0	0.0	66.9	0.0	0.0	0.0

Appendix C. Table continued from previous page…

730m Radius Circle									
	Cover Type								
Site Name	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Upper Pelt Creek	0.0	50.8	7.5	0.0	0.0	41.7	0.0	0.0	0.0
Upper Timber Creek	0.0	7.7	6.7	5.6	4.1	37.2	9.8	28.8	0.0
West Branch Elk Creek	0.0	5.9	3.8	1.8	0.0	35.4	11.8	2.7	38.7

Appendix D. *A priori* hypotheses testing effects of habitat specific covariates on initial occupancy, extinction and colonization rates at the Biscuit, Quartz and Timbered Rock Fires in southwest Oregon from 2003 - 2006, using open population occupancy modeling in program MARK.

Model	# of Variables
EARLY + RFL + RFM + NRFL + NRFM + HIGH + SALV	7
EARLY + RFL + NRFL + MOD + HIGH + SALV	6
EARLY + RFL + NRFL + HIMOD	4
EARLY + NRFL + NRFM + HIGH + SALV	5
EARLY + NRFL + NRFM + HIGH	4
RFL + NRFL + RFM + NRFM + HIGH + SALV	6
RFL + NRFL + RFM + NRFM + HIGH	5
RFL + NRFL + RFM + NRFM + UNSUIT	5
RFL + NRFL + HIGH + SALV	4
RFL + NRFL + HIGH	3
RFL + NRFL + MOD + HIGH + SALV	5
RFL + NRFL + HIMOD + SALV	4
RFL + NRFL + LOST	3
RFL + NRFL + UNSUIT	3
RFL + NRFL	2
NRFL + NRFM + HIGH + SALV	4
NRFL + NRFM + HIGH	3
NRFL + NRFM + UNSUIT	3
NRFL + HIGH + SALV	3
NRFL + HIGH	2
NRFL + MOD + HIGH + SALV	4
NRFL + HIMOD + SALV	3
NRFL + LOST	2
NRFL + UNSUIT	2
RF + NRF + HIGH + SALV	4
RF + NRF + HIGH	3
RF + NRF + LOST	3
RF + NRF + UNSUIT	3
RF + NRF	2
NRF + HIGH + SALV	3
NRF + HIGH	2
NRF + LOST	2
NRF + UNSUIT	2
SUIT + HIGH + SALV	3
SUIT + HIGH	2
SUIT + LOST	2
LOW + MOD + HIGH + SALV	4
LOW + MOD + HIGH	3
LOW + MOD + UNSUIT	3
LOW + UNSUIT	2
LOW + HIMOD	2
MOD + HIGH + SALV	3
MOD + HIGH	2
HIMOD + SALV	3
HIGH + SALV	2

Appendix E. Model selection results for initial occupancy parameters including covariates using open population occupancy models describing post-fire occupancy rates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 - 2006.

Model	AICc	ΔAICc	Weight	K	Deviance
{Ψ(RFLc+EDGEc)(Base Model Structure)}	473.473	0.000	0.073	8	456.513
{Ψ(RFLc)(Base Model Structure)}	474.040	0.567	0.055	7	459.298
{Ψ(EDGEc)(Base Model Structure)}	474.463	0.990	0.044	7	459.722
{Ψ(lnRFLc)(Base Model Structure)}	474.703	1.229	0.039	7	459.961
{Ψ(RFc)(Base Model Structure)}	474.933	1.460	0.035	7	460.191
{Ψ(EDGEc+EDGE2c)(Base Model Structure)}	475.578	2.104	0.025	8	458.618
{Ψ(lnLOWc)(Base Model Structure)}	476.007	2.534	0.020	7	461.265
{Ψ(LOWc)(Base Model Structure)}	476.040	2.567	0.020	7	461.299
{Ψ(lnEDGEc)(Base Model Structure)}	476.049	2.576	0.020	7	461.307
{Ψ(RFLc+NRFLc)(Base Model Structure)}	476.088	2.615	0.020	8	459.128
{Ψ(EDGEhr)(Base Model Structure)}	476.209	2.736	0.018	7	461.468
{Ψ(UNSUITc)(Base Model Structure)}	476.320	2.847	0.017	7	461.578
{Ψ(SUITc)(Base Model Structure)}	476.320	2.847	0.017	7	461.578
{Ψ(lnEDGEhr)(Base Model Structure)}	476.420	2.947	0.017	7	461.678
{Ψ(RFc+lnNRFc)(Base Model Structure)}	476.431	2.957	0.017	8	459.471
{Ψ(lnRFc)(Base Model Structure)}	476.631	3.157	0.015	7	461.889
{Ψ(lnUNSUITc)(Base Model Structure)}	476.778	3.305	0.014	7	462.036
{Ψ(lnSUITc)(Base Model Structure)}	476.822	3.349	0.014	7	462.080
{(Base Model Structure)}	476.930	3.457	0.013	6	464.377
{Ψ(SUITc+HIGHc+lnSALVhr)(Base Model Structure)}	477.283	3.810	0.011	9	458.076
{Ψ(HIMODc)(Base Model Structure)}	477.324	3.851	0.011	7	462.583
{Ψ(HIGHc)(Base Model Structure)}	477.351	3.878	0.010	7	462.610
{Ψ(RFLc+NRFLc+HIMODc+lnSALVhr)(Base Model Structure)}	477.403	3.930	0.010	10	455.916
{Ψ(RFLc+NRFLc+HIGHc+lnSALVhr)(Base Model Structure)}	477.410	3.936	0.010	10	455.923
{Ψ(LOSTc)(Base Model Structure)}	477.469	3.996	0.010	7	462.728
{Ψ(lnRFMhr)(Base Model Structure)}	477.501	4.028	0.010	7	462.759
{Ψ(RFMhr)(Base Model Structure)}	477.624	4.151	0.009	7	462.882
{Ψ(NRFLc)(Base Model Structure)}	477.636	4.163	0.009	7	462.894
{Ψ(lnNRFLc)(Base Model Structure)}	477.670	4.197	0.009	7	462.928
{Ψ(lnLOSTc)(Base Model Structure)}	477.686	4.213	0.009	7	462.944

Appendix E. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{Ψ(lnHIGHc)(Base Model Structure)}	477.826	4.352	0.008	7	463.084
{Ψ(RFc+lnNRFc+HIGHc)(Base Model Structure)}	477.829	4.355	0.008	9	458.621
{Ψ(lnLOWc+HIMODc)(Base Model Structure)}	477.866	4.393	0.008	8	460.906
{Ψ(EDGEhr+EDGE2hr)(Base Model Structure)}	477.875	4.402	0.008	8	460.916
{Ψ(lnNRFc)(Base Model Structure)}	477.879	4.406	0.008	7	463.137
{Ψ(SUITc+HIGHc)(Base Model Structure)}	477.938	4.465	0.008	8	460.979
{Ψ(NRFMhr)(Base Model Structure)}	477.968	4.495	0.008	7	463.226
{Ψ(RFLc+NRFLc+HIGHc)(Base Model Structure)}	477.983	4.509	0.008	9	458.774
{Ψ(NRFLc+UNSUITc)(Base Model Structure)}	478.042	4.568	0.007	8	461.082
{Ψ(RFhr)(Base Model Structure)}	478.080	4.606	0.007	7	463.337
{Ψ(NRFc)(Base Model Structure)}	478.119	4.646	0.007	7	463.377
{Ψ(lnLOWc+UNSUITc)(Base Model Structure)}	478.186	4.712	0.007	8	461.226
{Ψ(MODc)(Base Model Structure)}	478.209	4.736	0.007	7	463.468
{Ψ(NRFMc)(Base Model Structure)}	478.227	4.754	0.007	7	463.485
{Ψ(RFLc+NRFLc+LOSTc)(Base Model Structure)}	478.319	4.846	0.006	9	459.111
{Ψ(RFLc+NRFLc+UNSUITc)(Base Model Structure)}	478.334	4.860	0.006	9	459.125
{Ψ(lnNRFc+UNSUITc)(Base Model Structure)}	478.376	4.902	0.006	8	461.416
{Ψ(SUITc+LOSTc)(Base Model Structure)}	478.530	5.056	0.006	8	461.570
{Ψ(lnHIMODhr)(Base Model Structure)}	478.579	5.106	0.006	7	463.837
{Ψ(NRFLc+NRFMhr+UNSUITc)(Base Model Structure)}	478.580	5.107	0.006	9	459.372
{Ψ(RFc+lnNRFc+UNSUITc)(Base Model Structure)}	478.626	5.153	0.006	9	459.418
{Ψ(RFc+lnNRFc+LOSTc)(Base Model Structure)}	478.663	5.190	0.005	9	459.455
{Ψ(RFLhr)(Base Model Structure)}	478.670	5.197	0.005	7	463.928
{Ψ(lnSALVhr)(Base Model Structure)}	478.692	5.218	0.005	7	463.950
{Ψ(EARLYhr)(Base Model Structure)}	478.716	5.243	0.005	7	463.974
{Ψ(lnHIMODc)(Base Model Structure)}	478.722	5.249	0.005	7	463.980
{Ψ(lnUNSUIThr)(Base Model Structure)}	478.738	5.265	0.005	7	463.996
{Ψ(lnMODhr)(Base Model Structure)}	478.783	5.310	0.005	7	464.042
{Ψ(lnNRFc+HIGHc)(Base Model Structure)}	478.812	5.339	0.005	8	461.853
{Ψ(lnEARLYhr)(Base Model Structure)}	478.856	5.383	0.005	7	464.114

Appendix E. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{Ψ(lnNRFMhr)(Base Model Structure)}	478.903	5.430	0.005	7	464.161
{Ψ(lnRFhr)(Base Model Structure)}	478.905	5.432	0.005	7	464.163
{Ψ(SALVc)(Base Model Structure)}	478.911	5.438	0.005	7	464.169
{Ψ(RFMc)(Base Model Structure)}	478.922	5.449	0.005	7	464.181
{Ψ(lnEARLYc)(Base Model Structure)}	478.933	5.459	0.005	7	464.191
{Ψ(lnMODc)(Base Model Structure)}	478.951	5.477	0.005	7	464.209
{Ψ(UNSUIThr)(Base Model Structure)}	478.972	5.499	0.005	7	464.231
{Ψ(SUIThr)(Base Model Structure)}	478.972	5.499	0.005	7	464.231
{Ψ(HIMODc+lnSALVhr)(Base Model Structure)}	478.977	5.504	0.005	8	462.016
{Ψ(lnLOWhr)(Base Model Structure)}	478.981	5.508	0.005	7	464.239
{Ψ(lnSALVc)(Base Model Structure)}	478.986	5.512	0.005	7	464.244
{Ψ(lnSUIThr)(Base Model Structure)}	479.007	5.533	0.005	7	464.265
{Ψ(lnRFMc)(Base Model Structure)}	479.017	5.544	0.005	7	464.276
{Ψ(SALVhr)(Base Model Structure)}	479.020	5.547	0.005	7	464.278
{Ψ(LOWhr)(Base Model Structure)}	479.021	5.548	0.005	7	464.279
{Ψ(lnHIGHhr)(Base Model Structure)}	479.040	5.567	0.004	7	464.299
{Ψ(lnRFLhr)(Base Model Structure)}	479.048	5.575	0.004	7	464.306
{Ψ(LOSThr)(Base Model Structure)}	479.056	5.583	0.004	7	464.315
{Ψ(lnLOSThr)(Base Model Structure)}	479.060	5.586	0.004	7	464.318
{Ψ(MODhr)(Base Model Structure)}	479.080	5.607	0.004	7	464.339
{Ψ(lnNRFMc)(Base Model Structure)}	479.081	5.608	0.004	7	464.340
{Ψ(lnNRFLhr)(Base Model Structure)}	479.103	5.630	0.004	7	464.361
{Ψ(NRFhr)(Base Model Structure)}	479.103	5.630	0.004	7	464.361
{Ψ(HIGHhr)(Base Model Structure)}	479.104	5.630	0.004	7	464.362
{Ψ(lnNRFhr)(Base Model Structure)}	479.110	5.637	0.004	7	464.368
{Ψ(NRFLhr)(Base Model Structure)}	479.114	5.640	0.004	7	464.372
{Ψ(HIMODhr)(Base Model Structure)}	479.119	5.646	0.004	7	464.377
{Ψ(NRFLc+HIMODc+lnSALVhr)(Base Model Structure)}	479.126	5.652	0.004	9	459.917
{Ψ(NRFLc+HIGHc)(Base Model Structure)}	479.126	5.653	0.004	8	462.166
{Ψ(NRFLc+HIGHc+lnSALVhr)(Base Model Structure)}	479.207	5.733	0.004	9	459.998

Appendix E. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{Ψ(HIGHc+lnSALVhr)(Base Model Structure)}	479.239	5.765	0.004	8	462.279
{Ψ(lnLOWc+MODc+HIGHc+lnSALVhr)(Base Model Structure)}	479.291	5.817	0.004	10	457.804
{Ψ(MODc+HIGHc)(Base Model Structure)}	479.478	6.005	0.004	8	462.518
{Ψ(EARLYhr+RFLc+NRFLc+HIMODc+lnSALVhr)(Base Model Structure)}	479.526	6.053	0.004	11	455.730
{Ψ(RFLc+lnRFMhr+NRFLc+NRFMhr+HIGHc+lnSALVhr)(Base Model Structure)	479.566	6.093	0.003	12	453.429
{Ψ(RFLc+lnRFMhr+NRFLc+NRFMhr+UNSUITc)(Base Model Structure)}	479.580	6.107	0.003	11	455.784
{Ψ(lnNRFc+LOSTc)(Base Model Structure)}	479.591	6.117	0.003	8	462.630
{Ψ(NRFLc+LOSTc)(Base Model Structure)}	479.615	6.142	0.003	8	462.655
{Ψ(RFLc+lnRFMhr+NRFLc+NRFMhr+HIGHc)(Base Model Structure)}	479.683	6.209	0.003	11	455.887
{Ψ(lnNRFc+HIGHc+lnSALVhr)(Base Model Structure)}	479.698	6.225	0.003	9	460.490
{Ψ(RFLc+NRFLc+MODc+HIGHc+lnSALVhr)(Base Model Structure)}	479.717	6.244	0.003	11	455.921
{Ψ(lnLOWc+MODc+HIGHc)(Base Model Structure)}	480.072	6.599	0.003	9	460.865
{Ψ(lnLOWc+MODc+UNSUITc)(Base Model Structure)}	480.271	6.798	0.002	9	461.063
{Ψ(EARLYhr+RFLc+NRFLc+HIMODc)(Base Model Structure)}	480.425	6.952	0.002	10	458.939
{Ψ(NRFLc+NRFMhr+HIGHc+lnSALVhr)(Base Model Structure)}	480.920	7.446	0.002	10	459.433
{Ψ(NRFLc+NRFMhr+HIGHc)(Base Model Structure)}	480.958	7.485	0.002	9	461.750
{Ψ(MODc+HIGHc+lnSALVhr)(Base Model Structure)}	481.192	7.719	0.002	9	461.984
{Ψ(NRFLc+MODc+HIGHc+lnSALVhr)(Base Model Structure)}	481.232	7.759	0.002	10	459.745
{Ψ(EARLYhr+RFLc+lnRFMhr+NRFLc+NRFMhr+HIGHc+lnSALVhr)(Base Model Structure)}	481.842	8.368	0.001	13	453.331
{Ψ(EARLYhr+NRFLc+NRFMhr+HIGHc)(Base Model Structure)}	481.909	8.435	0.001	10	460.422
{Ψ(EARLYhr+RFLc+lnRFMhr+NRFLc+NRFMhr+HIGHc)(Base Model Structure)	481.989	8.516	0.001	12	455.852
{Global}	811.678	350.967	0.000	92	368.405

Appendix F. Model selection results for extinction parameters including covariates using open population occupancy models describing post-fire occupancy rates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 - 2006.

Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) ε(lnUNSUITc+EDGEhr)}	464.614	0.000	0.266	8	447.654
{(Base Model Structure) ε(lnUNSUITc)}	466.503	1.888	0.104	7	451.761
{(Base Model Structure) ε(NRFLc+lnUNSUITc)}	467.510	2.895	0.063	8	450.550
{(Base Model Structure) ε(LOWc+lnUNSUITc)}	468.269	3.655	0.043	8	451.309
{(Base Model Structure) ε(RFLhr+NRFLc+lnUNSUITc)}	468.305	3.690	0.042	9	449.096
{(Base Model Structure) ε(NRFc+lnUNSUITc)}	468.399	3.784	0.040	8	451.438
{(Base Model Structure) ε(UNSUITc)}	468.771	4.157	0.033	7	454.029
{(Base Model Structure) ε(SUITc)}	468.771	4.157	0.033	7	454.029
{(Base Model Structure) ε(lnSUITc)}	468.906	4.291	0.031	7	454.164
{(Base Model Structure) ε(NRFLc+NRFMc+lnUNSUITc)}	469.214	4.600	0.027	9	450.006
{(Base Model Structure) ε(NRFc)}	469.893	5.278	0.019	7	455.151
{(Base Model Structure) ε(NRFLc)}	470.293	5.678	0.016	7	455.551
{(Base Model Structure) ε(LOWc+MODhr+lnUNSUITc)}	470.328	5.713	0.015	9	451.120
{(Base Model Structure) ε(LOWc)}	470.507	5.892	0.014	7	455.765
{(Base Model Structure) ε(lnNRFc)}	470.551	5.936	0.014	7	455.809
{(Base Model Structure) ε(lnRFMhr)}	470.651	6.036	0.013	7	455.909
{(Base Model Structure) ε(SUITc+LOSTc}	470.690	6.076	0.013	8	453.730
{(Base Model Structure) ε(SUITc+HIGHc}	470.700	6.086	0.013	8	453.740
{(Base Model Structure) ε(lnLOWc)}	470.844	6.229	0.012	7	456.102
{(Base Model Structure) ε(SUITc+HIMODc}	470.957	6.342	0.011	8	453.997
{(Base Model Structure) ε(lnNRFLc)}	471.039	6.424	0.011	7	456.297
{(Base Model Structure) ε(NRFc+LOSTc)}	471.045	6.431	0.011	8	454.085
{(Base Model Structure) ε(lnRFhr+NRFc)}	471.046	6.432	0.011	8	454.086
{(Base Model Structure) ε(RFLhr+lnRFMhr+NRFLc+NRFMc+lnUNSUITc)}	471.062	6.447	0.011	11	447.265
{(Base Model Structure) ε(NRFc+HIGHc)}	471.453	6.839	0.009	8	454.493
{(Base Model Structure) ε(NRFLc+LOSTc)}	471.615	7.000	0.008	8	454.655
{(Base Model Structure) ε(lnRFLhr+NRFLc)}	471.663	7.049	0.008	8	454.703
{(Base Model Structure) ε(LOSTc)}	471.878	7.263	0.007	7	457.136
{(Base Model Structure) ε(NRFLc+HIGHc)}	472.161	7.546	0.006	8	455.201
{(Base Model Structure) ε(LOWc+HIMODc)}	472.720	8.105	0.005	8	455.760
{(Base Model Structure) ε(lnRFhr+NRFc+LOSTc)}	472.862	8.248	0.004	9	453.654

Appendix F. Continued…					
Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) ε(SUITc+HIGHc+SALVc}	472.900	8.286	0.004	9	453.692
{(Base Model Structure) ε(lnRFhr+NRFc+HIGHc)}	472.915	8.301	0.004	9	453.707
{(Base Model Structure) ε(SUITc+HIMODc+SALVc}	473.204	8.590	0.004	9	453.996
{(Base Model Structure) ε(NRFc+HIGHc+SALVc)}	473.260	8.645	0.004	9	454.051
{(Base Model Structure) ε(NRFLc+NRFMc+HIGHc)}	473.384	8.769	0.003	9	454.176
{(Base Model Structure) ε(SALVc+HIGHc)}	473.455	8.841	0.003	8	456.495
{(Base Model Structure) ε(NRFLc+HIGHc+SALVc)}	473.774	9.159	0.003	9	454.566
{(Base Model Structure) ε(lnRFLhr+NRFLc+HIGHc)}	473.827	9.213	0.003	9	454.619
{(Base Model Structure) ε(SALVc)}	474.111	9.496	0.002	7	459.369
{(Base Model Structure) ε(NRFhr)}	474.119	9.504	0.002	7	459.377
{(Base Model Structure) ε(HIMODc+SALVc)}	474.207	9.593	0.002	8	457.247
{(Base Model Structure) ε(NRFLhr)}	474.334	9.720	0.002	7	459.592
{(Base Model Structure) ε(NRFLc+HIMODc+SALVc)}	474.356	9.742	0.002	9	455.148
{(Base Model Structure) ε(LOWc+MODhr+HIGHc)}	474.396	9.781	0.002	9	455.188
{(Base Model Structure) ε(lnLOSTc)}	474.520	9.905	0.002	7	459.778
{(Base Model Structure) ε(EDGEhr)}	474.551	9.937	0.002	7	459.809
{(Base Model Structure) ε(lnEARLYc+NRFLc+NRFMc+HIGHc)}	474.659	10.045	0.002	10	453.173
{(Base Model Structure) ε(lnEDGEc)}	474.659	10.045	0.002	7	459.917
{(Base Model Structure) ε(lnEDGEhr)}	474.687	10.073	0.002	7	459.945
{(Base Model Structure) ε(RFMhr)}	474.751	10.137	0.002	7	460.009
{(Base Model Structure) ε(lnEARLYc+NRFLc+NRFMc+HIGHc+SALVc)}	475.058	10.443	0.001	11	451.262
{(Base Model Structure) ε(lnRFhr+NRFc+HIGHc+SALVc)}	475.103	10.488	0.001	10	453.616
{(Base Model Structure) ε(lnNRFhr)}	475.224	10.610	0.001	7	460.482
{(Base Model Structure) ε(NRFLc+NRFMc+HIGHc+SALVc)}	475.241	10.627	0.001	10	453.755
{(Base Model Structure) ε(lnLOSThr)}	475.358	10.743	0.001	7	460.616
{(Base Model Structure) ε(lnRFhr)}	475.426	10.812	0.001	7	460.684
{(Base Model Structure) ε(lnUNSUIThr)}	475.486	10.872	0.001	7	460.744
{(Base Model Structure) ε(MODhr+HIGHc+SALVc)}	475.501	10.887	0.001	9	456.293
{(Base Model Structure) ε(RFLhr+lnRFMhr+NRFLc+NRFMc+HIGHc)}	475.565	10.951	0.001	11	451.769
{(Base Model Structure) ε(lnEARLYc)}	475.659	11.044	0.001	7	460.917
{(Base Model Structure) ε(EDGEc+EDGE2c)}	475.720	11.106	0.001	8	458.760
{(Base Model Structure) ε(LOWhr)}	475.860	11.246	0.001	7	461.119

Appendix F. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) ε(lnEARLYc+RFLhr+NRFLc+HIMODc)}	475.894	11.280	0.001	10	454.407
{(Base Model Structure) ε(lnRFLhr+NRFLc+HIGHc+SALVc)}	475.933	11.319	0.001	10	454.447
{(Base Model Structure) ε(NRFLc+MODhr+HIGHc+SALVc)}	475.999	11.384	0.001	10	454.512
{(Base Model Structure) ε(lnRFMc)}	476.100	11.485	0.001	7	461.358
{(Base Model Structure) ε(lnRFLhr+NRFLc+HIMODc+SALVc)}	476.166	11.551	0.001	10	454.679
{(Base Model Structure) ε(UNSUIThr)}	476.205	11.591	0.001	7	461.463
{(Base Model Structure) ε(SUIThr)}	476.205	11.591	0.001	7	461.463
{(Base Model Structure) ε(lnEARLYc+RFLhr+lnRFMhr+NRFLc+NRFMc+HIGHc+SALVc)}	476.227	11.612	0.001	13	447.717
{(Base Model Structure) ε(LOWc+MODhr+HIGHc+SALVc)}	476.384	11.769	0.001	10	454.897
{(Base Model Structure) ε(lnSALVc)}	476.425	11.810	0.001	7	461.683
{(Base Model Structure) ε(lnNRFLhr)}	476.476	11.861	0.001	7	461.734
{(Base Model Structure) ε(HIMODc)}	476.479	11.865	0.001	7	461.737
{(Base Model Structure) ε(EDGEhr+EDGE2hr)}	476.592	11.978	0.001	8	459.632
{(Base Model Structure) ε(LOSThr)}	476.620	12.006	0.001	7	461.878
{(Base Model Structure) ε(HIGHc)}	476.633	12.019	0.001	7	461.892
{(Base Model Structure) ε(RFhr)}	476.769	12.155	0.001	7	462.028
{(Base Model Structure) ε(lnSUIThr)}	476.813	12.199	0.001	7	462.071
{(Base Model Structure) ε(EDGEc)}	476.894	12.280	0.001	7	462.153
{(Base Model Structure)}	476.930	12.315	0.001	6	464.377
{(Base Model Structure) ε(lnRFc)}	477.177	12.563	0.000	7	462.436
{(Base Model Structure) ε(RFMc)}	477.267	12.652	0.000	7	462.525
{(Base Model Structure) ε(RFLhr+lnRFMhr+NRFLc+NRFMc+HIGHc+SALVc)}	477.323	12.709	0.000	12	451.186
{(Base Model Structure) ε(MODhr)}	477.362	12.747	0.000	7	462.620
{(Base Model Structure) ε(lnMODhr)}	477.390	12.776	0.000	7	462.648
{(Base Model Structure) ε(HIMODhr)}	477.422	12.807	0.000	7	462.680
{(Base Model Structure) ε(lnLOWhr)}	477.433	12.819	0.000	7	462.692
{(Base Model Structure) ε(lnEARLYc+RFLhr+NRFLc+HIMODc+SALVc)}	477.474	12.860	0.000	11	453.678
{(Base Model Structure) ε(EARLYc)}	477.481	12.867	0.000	7	462.739
{(Base Model Structure) ε(SALVhr)}	477.588	12.973	0.000	7	462.846
{(Base Model Structure) ε(MODhr+HIGHc)}	477.603	12.988	0.000	8	460.643
{(Base Model Structure) ε(lnHIGHc)}	477.649	13.034	0.000	7	462.907

Appendix F. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) ε(lnHIMODc)}	477.776	13.162	0.000	7	463.034
{(Base Model Structure) ε(lnSALVhr)}	477.804	13.189	0.000	7	463.062
{(Base Model Structure) ε(lnRFLhr)}	477.878	13.264	0.000	7	463.137
{(Base Model Structure) ε(lnRFLc)}	477.893	13.278	0.000	7	463.151
{(Base Model Structure) ε(lnHIMODhr)}	477.988	13.374	0.000	7	463.246
{(Base Model Structure) ε(RFc)}	478.079	13.464	0.000	7	463.337
{(Base Model Structure) ε(MODc)}	478.123	13.509	0.000	7	463.381
{(Base Model Structure) ε(lnRFLhr+NRFLc+MODhr+HIGHc+SALVc)}	478.234	13.620	0.000	11	454.438
{(Base Model Structure) ε(lnMODc)}	478.334	13.720	0.000	7	463.592
{(Base Model Structure) ε(RFLhr)}	478.343	13.728	0.000	7	463.601
{(Base Model Structure) ε(HIGHhr)}	478.575	13.961	0.000	7	463.833
{(Base Model Structure) ε(RFLc)}	478.632	14.018	0.000	7	463.890
{(Base Model Structure) ε(NRFMc)}	478.696	14.082	0.000	7	463.954
{(Base Model Structure) ε(EARLYhr)}	478.760	14.146	0.000	7	464.018
{(Base Model Structure) ε(lnEARLYhr)}	478.839	14.225	0.000	7	464.098
{(Base Model Structure) ε(lnNRFMhr)}	478.907	14.292	0.000	7	464.165
{(Base Model Structure) ε(lnHIGHhr)}	478.942	14.328	0.000	7	464.201
{(Base Model Structure) ε(lnNRFMc)}	478.956	14.342	0.000	7	464.214
{(Base Model Structure) ε(NRFMhr)}	479.054	14.440	0.000	7	464.312
{GLOBAL}	542.994	78.379	0.000	56	368.405

Appendix G. Model selection results for colonization parameters including covariates using open population occupancy models describing post-fire occupancy rates at the Biscuit, Quartz and Timbered Rock Fires in southwestern Oregon from 2003 - 2006.

Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) γ(NRFLc+lnHIGHhr)}	460.711	0.000	0.135	8	443.751
{(Base Model Structure) γ(lnNRFc+lnHIGHhr)}	461.436	0.725	0.094	8	444.476
{(Base Model Structure) γ(lnRFc+lnNRFc+lnHIGHhr)}	461.984	1.273	0.071	9	442.776
{(Base Model Structure) γ(NRFLc+NRFMhr+lnHIGHhr)}	462.270	1.559	0.062	9	443.062
{(Base Model Structure) γ(NRFLc+lnHIGHhr+SALVc)}	462.594	1.883	0.053	9	443.386
{(Base Model Structure) γ(RFLc+NRFLc+lnHIGHhr)}	462.628	1.916	0.052	9	443.420
{(Base Model Structure) γ(LOWc+lnMODc+lnHIGHhr)}	462.817	2.106	0.047	9	443.609
{(Base Model Structure) γ(lnNRFc+lnHIGHhr+SALVc)}	462.892	2.181	0.045	9	443.684
{(Base Model Structure) γ(NRFLc+lnHIGHhr+lnEDGEc)}	462.954	2.243	0.044	9	443.746
{(Base Model Structure) γ(LOWc+lnHIMODhr)}	463.081	2.370	0.041	8	446.121
{(Base Model Structure) γ(lnRFc+lnNRFc+lnHIGHhr+SALVc)}	463.266	2.555	0.038	10	441.779
{(Base Model Structure) γ(NRFLc+lnHIMODhr+SALVc)}	463.428	2.717	0.035	9	444.220
{(Base Model Structure) γ(SUITc+lnHIGHhr)}	463.479	2.768	0.034	8	446.519
{(Base Model Structure) γ(NRFLc+lnMODc+lnHIGHhr+SALVc)}	464.057	3.346	0.025	10	442.571
{(Base Model Structure) γ(NRFLc+NRFMhr+lnHIGHhr+SALVc)}	464.214	3.503	0.023	10	442.727
{(Base Model Structure) γ(RFLc+RFMc+NRFLc+NRFMhr+lnUNSUITc)}	464.370	3.659	0.022	11	440.574
{(Base Model Structure) γ(EARLYc+NRFLc+NRFMhr+lnHIGHhr)}	464.389	3.678	0.021	10	442.903
{(Base Model Structure) γ(RFLc+NRFLc+lnHIGHhr+SALVc)}	464.637	3.926	0.019	10	443.150
{(Base Model Structure) γ(LOWc+lnMODc+lnHIGHhr+SALVc)}	464.787	4.076	0.018	10	443.301
{(Base Model Structure) γ(SUITc+lnHIGHhr+SALVc)}	465.037	4.325	0.015	9	445.828
{(Base Model Structure) γ(RFLc+NRFLc+lnHIMODhr+SALVc)}	465.577	4.866	0.012	10	444.091
{(Base Model Structure) γ(SUITc+lnHIMODhr)}	465.861	5.150	0.010	8	448.901
{(Base Model Structure) γ(lnMODc+lnHIGHhr+SALVc)}	466.007	5.296	0.010	9	446.800
{(Base Model Structure) γ(lnMODc+lnHIGHhr)}	466.162	5.451	0.009	8	449.201
{(Base Model Structure) γ(EARLYc+RFLc+NRFLc+lnHIMODhr)}	466.257	5.546	0.008	10	444.770
{(Base Model Structure) γ(RFLc+NRFLc+lnMODc+lnHIGHhr+SALVc)}	466.298	5.587	0.008	11	442.502
{(Base Model Structure) γ(EARLYc+NRFLc+NRFMhr+lnHIGHhr+SALVc)}	466.311	5.599	0.008	11	442.515
{(Base Model Structure) γ(SUITc+lnHIMODhr+SALVc)}	466.448	5.737	0.008	9	447.240
{(Base Model Structure) γ(EARLYc+RFLc+NRFLc+lnHIMODhr+SALVc)}	467.741	7.029	0.004	11	443.945
{(Base Model Structure) γ(SALVc+lnHIGHhr)}	467.966	7.255	0.004	8	451.006

Appendix G. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) γ(lnRFc+lnNRFc+lnUNSUITc)}	468.723	8.012	0.002	9	449.515
{(Base Model Structure) γ(lnUNSUITc)}	469.279	8.568	0.002	7	454.537
{(Base Model Structure) γ(SALVc)}	469.873	9.162	0.001	7	455.132
{(Base Model Structure) γ(LOWc)}	470.125	9.414	0.001	7	455.383
{(Base Model Structure) γ(UNSUITc)}	470.318	9.607	0.001	7	455.577
{(Base Model Structure) γ(SUITc)}	470.318	9.607	0.001	7	455.577
{(Base Model Structure) γ(lnNRFc)}	470.571	9.860	0.001	7	455.830
{(Base Model Structure) γ(lnNRFc+lnUNSUITc)}	470.711	10.000	0.001	8	453.751
{(Base Model Structure) γ(NRFc)}	470.797	10.086	0.001	7	456.056
{(Base Model Structure) γ(lnSUITc)}	470.874	10.162	0.001	7	456.132
{(Base Model Structure) γ(lnHIGHhr)}	471.027	10.316	0.001	7	456.286
{(Base Model Structure) γ(NRFLc)}	471.131	10.420	0.001	7	456.389
{(Base Model Structure) γ(lnRFc+lnNRFc)}	471.132	10.421	0.001	8	454.172
{(Base Model Structure) γ(LOWc+lnUNSUITc)}	471.245	10.534	0.001	8	454.285
{(Base Model Structure) γ(lnLOWc)}	471.276	10.565	0.001	7	456.534
{(Base Model Structure) γ(NRFLc+lnUNSUITc)}	471.414	10.703	0.001	8	454.454
{(Base Model Structure) γ(lnNRFLc)}	471.493	10.782	0.001	7	456.751
{(Base Model Structure) γ(NRFLc+LOSTc)}	472.206	11.495	0.000	8	455.246
{(Base Model Structure) γ(lnNRFc+LOSTc)}	472.282	11.571	0.000	8	455.322
{(Base Model Structure) γ(RFMc)}	472.302	11.591	0.000	7	457.561
{(Base Model Structure) γ(RFLc+NRFLc)}	472.321	11.610	0.000	8	455.361
{(Base Model Structure) γ(SALVhr)}	472.457	11.746	0.000	7	457.715
{(Base Model Structure) γ(RFLc+NRFLc+LOSTc)}	472.596	11.885	0.000	9	453.388
{(Base Model Structure) γ(lnSUITc+LOSTc)}	472.675	11.964	0.000	8	455.715
{(Base Model Structure) γ(lnRFc+lnNRFc+LOSTc)}	473.170	12.459	0.000	9	453.962
{(Base Model Structure) γ(HIGHhr)}	473.254	12.543	0.000	7	458.512
{(Base Model Structure) γ(RFLc+NRFLc+lnUNSUITc)}	473.478	12.766	0.000	9	454.269
{(Base Model Structure) γ(LOWc+lnMODc+lnUNSUITc)}	473.487	12.776	0.000	9	454.279
{(Base Model Structure) γ(lnHIMODhr)}	473.601	12.890	0.000	7	458.860
{(Base Model Structure) γ(HIMODhr)}	474.256	13.545	0.000	7	459.514
{(Base Model Structure) γ(lnSALVc)}	474.260	13.549	0.000	7	459.518

Appendix G. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) γ(RFLc)}	475.082	14.371	0.000	7	460.340
{(Base Model Structure) γ(EARLYc)}	475.653	14.942	0.000	7	460.912
{(Base Model Structure) γ(LOSTc)}	476.118	15.407	0.000	7	461.376
{(Base Model Structure) γ(lnSUIThr)}	476.120	15.409	0.000	7	461.379
{(Base Model Structure) γ(lnEDGEc)}	476.149	15.438	0.000	7	461.407
{(Base Model Structure) γ(lnMODc)}	476.333	15.622	0.000	7	461.592
{(Base Model Structure) γ(lnLOSTc)}	476.695	15.984	0.000	7	461.953
{(Base Model Structure) γ(lnEARLYc)}	476.745	16.034	0.000	7	462.003
{(Base Model Structure) γ(EARLYhr)}	476.929	16.218	0.000	7	462.187
{(Base Model Structure)}	476.930	16.219	0.000	6	464.377
{(Base Model Structure)}	476.930	16.219	0.000	6	464.377
{(Base Model Structure) γ(lnLOWhr)}	476.969	16.258	0.000	7	462.227
{(Base Model Structure) γ(NRFMhr)}	477.180	16.468	0.000	7	462.438
{(Base Model Structure) γ(lnNRFhr)}	477.239	16.528	0.000	7	462.497
{(Base Model Structure) γ(UNSUIThr)}	477.329	16.617	0.000	7	462.587
{(Base Model Structure) γ(SUIThr)}	477.329	16.617	0.000	7	462.587
{(Base Model Structure) γ(lnNRFMhr)}	477.460	16.749	0.000	7	462.719
{(Base Model Structure) γ(lnNRFLhr)}	477.579	16.867	0.000	7	462.837
{(Base Model Structure) γ(lnSALVhr)}	477.590	16.879	0.000	7	462.848
{(Base Model Structure) γ(MODhr)}	477.614	16.903	0.000	7	462.872
{(Base Model Structure) γ(NRFhr)}	477.753	17.042	0.000	7	463.012
{(Base Model Structure) γ(lnRFc)}	477.833	17.122	0.000	7	463.091
{(Base Model Structure) γ(RFc)}	477.890	17.179	0.000	7	463.149
{(Base Model Structure) γ(lnRFLc)}	477.947	17.236	0.000	7	463.205
{(Base Model Structure) γ(MODc)}	477.958	17.247	0.000	7	463.216
{(Base Model Structure) γ(lnHIMODc)}	478.003	17.292	0.000	7	463.261
{(Base Model Structure) γ(EDGEc)}	478.084	17.373	0.000	7	463.342
{(Base Model Structure) γ(lnNRFMc)}	478.194	17.483	0.000	7	463.453
{(Base Model Structure) γ(lnMODhr)}	478.203	17.491	0.000	7	463.461
{(Base Model Structure) γ(LOWhr)}	478.271	17.560	0.000	7	463.530
{(Base Model Structure) γ(NRFLhr)}	478.373	17.662	0.000	7	463.631

Appendix G. Continued…

Model	AICc	ΔAICc	Weight	K	Deviance
{(Base Model Structure) γ(lnUNSUIThr)}	478.460	17.749	0.000	7	463.719
{(Base Model Structure) γ(LOSThr)}	478.613	17.902	0.000	7	463.871
{(Base Model Structure) γ(RFhr)}	478.684	17.973	0.000	7	463.942
{(Base Model Structure) γ(RFLhr)}	478.768	18.057	0.000	7	464.026
{(Base Model Structure) γ(HIGHc)}	478.805	18.094	0.000	7	464.064
{(Base Model Structure) γ(lnEDGEhr)}	478.948	18.237	0.000	7	464.206
{(Base Model Structure) γ(lnRFMhr)}	478.950	18.239	0.000	7	464.208
{(Base Model Structure) γ(lnRFhr)}	478.951	18.240	0.000	7	464.209
{(Base Model Structure) γ(EDGEhr)}	478.969	18.258	0.000	7	464.227
{(Base Model Structure) γ(RFMhr)}	479.007	18.295	0.000	7	464.265
{(Base Model Structure) γ(lnLOSThr)}	479.027	18.316	0.000	7	464.285
{(Base Model Structure) γ(lnEARLYhr)}	479.089	18.378	0.000	7	464.348
{(Base Model Structure) γ(lnHIGHc)}	479.108	18.397	0.000	7	464.366
{(Base Model Structure) γ(NRFMc)}	479.109	18.398	0.000	7	464.368
{(Base Model Structure) γ(HIMODc)}	479.117	18.406	0.000	7	464.375
{(Base Model Structure) γ(EDGEc+EDGE2c)}	480.291	19.580	0.000	8	463.331
{(Base Model Structure) γ(EDGEhr+EDGE2hr)}	481.146	20.434	0.000	8	464.186
{Global}	811.678	350.967	0.000	92	368.405

Appendix H. Northern spotted owls radio-tagged at the Timbered Rock and Quartz Fires, Oregon, USA.

Site Name	Owls Captured	Date Captured	Inside/Outside Fire
Timbered Rock Fire			
Alco Rock	Pair	♂ - 09/04 ♀ - 02/05	Inside
Flat Creek	Pair	♂ - 03/05 ♀ - 09/04	Inside
Miller Mountain	Pair	♂ - 09/04 ♀ - 09/04	Inside
Upper Timber Creek	Pair	♂ - 09/04 ♀ - 09/04	Inside
Gobblers Knob	Pair	♂ - 09/04 ♀ - 09/04	Inside
Hungry Elk	Pair	♂ - 03/05 ♀ - 03/05	Outside
Lower Morine	Pair	♂ - 02/05 ♀ - 02/05	Outside
South Boundary	Pair	♂ - 03/05 ♀ - 03/05	Outside
Oliver Springs	Pair	♂ - 03/05 ♀ - 03/05	Outside
Louis Creek	Pair	♂ - 09/04 ♀ - 09/04	Outside
Hawk Creek	Male	♂ - 09/05	Inside
Timbered Rock	Pair	♂ - 05/06 ♀ - 05/06	Inside
Quartz Fire			
Yale Creek	Pair	♂ - 04/05 ♀ - 06/05	Outside
Glade Creek	Male	♂ - 04/05	Inside

Appendix I. Post-fire diets of northern spotted owls at the Biscuit, Quartz and Timbered Rock Fires in southwest Oregon from 2002 – 2006.

Northern spotted owl (*Strix occidentalis caurina*) pellets were collected opportunistically during annual demographic surveys between March and August of each calendar year and occasionally during the non-breeding season for radio-tagged owls to assess post-fire diets of spotted owls. I calculated the biomass consumed by spotted owls following methods established by Forsman et al. (2004). Spotted owl diets were dominated by woodrats (*Neotoma* spp), northern flying squirrels (*Glaucomys sabrinus*) and rabbits/hares (Figure 1). Total numbers of individual prey items consumed varied widely and covered many different species (Table 1).

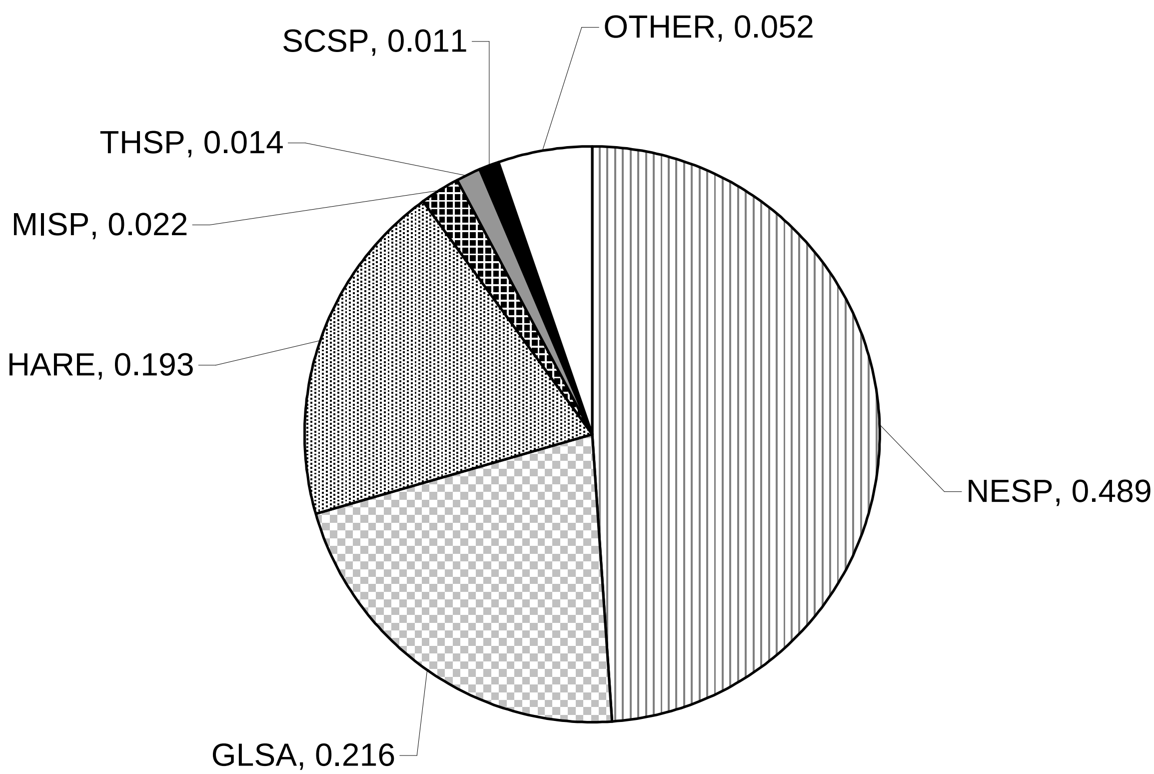


Figure 1**.** Proportion of biomass of prey items in collected spotted owl pellets at the Biscuit, Timbered Rock, and Quartz Fires in southwestern Oregon, 2002 – 2006. NESP = Woodrat species, GLSA = Northern flying squirrel, HARE = Rabbit/Hare species, MISP = *Microtus* species, THSP = *Thomomys* species, SCSP = *Scapanus* species, OTHER = birds, insects, bats, and other small mammals infrequently captured.

Appendix I - Table 1. Number of individual prey items by species found in spotted owl pellets at the Biscuit, Quartz and Timbered Rock Fires from 2002 - 2006.

Species	Mean Mass (g)	N
MAMMALS		
Soricidae		
Sorex spp - Unidentified Shrew	7	1
Talpidae		
Neurotrichus gibbsii - Shrew Mole	9	1
Scapanus orarius - Coast Mole	56	2
Scapanus spp - Unidentified Mole	56	10
Chiroptera		
Eptesicus fuscus - Big Brown Bat	15	1
Chiroptera spp - Unidentified Bat	10	2
Leporidae		
Lepus americanus - Snowshoe Hare	50 - 1400	4
Sylvilagus bachmani - Brush Rabbit	700	1
Leopridae - Unidentified Rabbit/Hare	50 - 1100	17
Scuridae		
Tamias spp - Unidentified Chipmunk	83	4
Glaucomys sabrinus - Northern Flying Squirrel	130	100
Geomyidae		
Thomomys spp - Unidentified Gopher	95	9
Muridae - Sigmodontinae		
Peromyscus maniculatus - Deer Mouse	22	18
Neotoma spp - Woodrat Species	285	103
Muridae - Arvicolinae		
Clethrionomys califonicus - Western Red-backed Vole	23	18
Arborimus longicaudus - Red Tree Vole	26	15
Microtus longicaudus - Long-tailed Vole	56	3
Microtus oregoni - Creeping Vole	20	4
Microtus montanus - Montane Vole	42	13
Microtus spp - Unidentified Vole	30	19
Microtus califonicus - California Vole	43	1
BIRDS		
Strigidae		
Strix occidentlis caurina - Spotted Owl (Juvenile)	400	1
Megascops kennicottii - Western screech owl	169	2
Corvidae		
Cyanocitta stelleri - Steller's Jay	128	1
Perisoreus canadensis - Gray Jay	73	1
Turdidae		
Ixoreus naevius - Varied Thrush	78	4
Thraupidae		
Piranga ludoviciana - Western Tanager	28	1
Fringillidae		
Carpodacus spp - Unidentified Finch	30	1

Appendix I - Table 1. Continued…		
Species	Mean Mass (g)	N
BIRDS Continued…		
Unidentified Birds		
Unidentified Medium Bird	70	2
Unidentified Small Bird	10 - 20	2
AMPHIBIANS		
Rana spp - Unidentified Frog	30	1
INSECTS		
Orthoptera - Tettigoniidae (Camel crickets)		
Cyphoderris monstosa - Great Grig	2	1
Coleoptera - Cerambycidae (Long-horned woodborers)		
Ergates spiculatus - Ponderosa Wood Borer	3	14

Appendix J. Percent of each cover type within annual, breeding and non-breeding season home ranges of northern spotted owls within and around the Quartz and Timbered Rock Fires.

Annual Home Range									
	Cover Type								
Owl	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Inside Fire									
Alco Rock Female	0.0	29.2	10.6	2.2	1.7	49.0	3.7	1.8	1.7
Alco Rock Male	0.0	32.7	2.2	6.4	4.6	33.0	12.2	3.7	5.2
Flat Creek Female	0.0	17.7	4.7	6.8	3.7	18.8	24.2	6.8	17.3
Flat Creek Male	0.0	23.2	4.1	7.2	4.2	23.1	10.2	5.6	22.3
Glade Creek Male	3.0	22.4	10.0	1.4	0.6	44.6	2.6	8.7	6.7
Gobblers Knob Female	0.4	30.7	13.5	0.9	1.7	27.2	10.7	5.9	9.1
Gobblers Knob Male	0.0	24.5	8.1	2.3	2.6	32.3	14.5	5.7	9.9
Miller Mountain Female	3.8	27.3	15.1	8.8	1.8	14.4	3.9	3.0	21.9
Miller Mountain Male	4.0	22.0	16.4	10.5	1.9	14.1	3.8	0.7	26.6
Upper Timber Male	0.0	28.0	7.3	4.7	2.3	38.5	7.9	10.6	0.6
Outside Fire									
Hungry Elk Female	0.2	13.8	22.2	0.5	0.0	55.2	3.4	2.4	2.4
Hungry Elk Male	0.1	8.2	19.8	0.5	0.0	64.8	1.9	1.6	3.1
Louis Creek Female	1.5	30.5	20.1	0.0	0.0	47.0	0.0	0.0	1.0
Louis Creek Male	0.9	32.6	23.3	0.7	0.0	42.4	0.0	0.0	0.0
Lower Morine Female	1.7	9.6	16.2	0.0	0.0	72.5	0.0	0.0	0.0
Lower Morine Male	0.7	15.3	17.2	0.0	0.0	66.7	0.0	0.0	0.0
Oliver Springs Male	0.0	41.5	17.4	0.0	0.0	38.0	1.8	0.1	1.1
South Boundary Female	0.0	40.7	17.5	0.8	0.0	35.0	1.5	0.0	4.5
South Boundary Male	0.0	34.9	13.0	1.1	0.0	43.4	0.3	0.5	6.9
Yale Creek Female	4.4	17.2	41.3	0.0	0.0	37.2	0.0	0.0	0.0

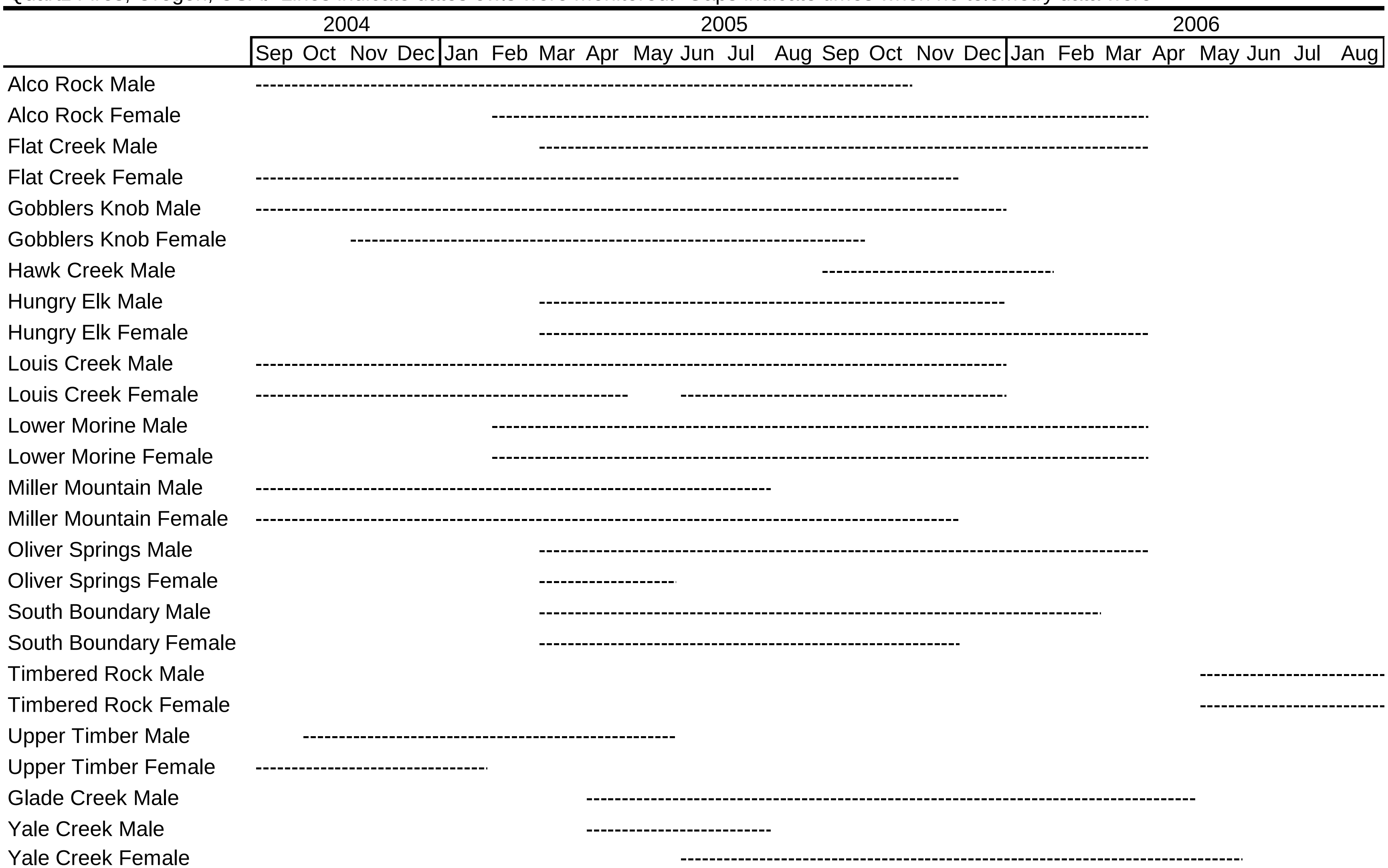
Appendix J. Continued…

Owl	Breeding Season Home Range								
	Cover Type								
	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Inside Fire									
Alco Rock Female	0.0	23.8	1.8	3.5	0.0	65.6	5.2	0.1	0.1
Alco Rock Male	0.0	31.8	1.8	6.3	1.0	41.1	13.8	1.5	2.7
Flat Creek Female	0.0	10.0	3.9	6.9	0.8	43.7	21.6	4.4	8.7
Flat Creek Male	0.0	20.5	5.4	3.8	3.3	27.7	17.5	8.0	13.8
Glade Creek Male	2.5	21.0	9.5	2.8	1.2	37.8	4.1	15.2	5.8
Gobblers Knob Female	0.9	23.9	11.7	3.6	1.5	28.5	9.9	8.6	11.3
Gobblers Knob Male	0.0	16.7	6.0	3.0	2.0	38.6	17.7	9.5	6.4
Miller Mountain Female	1.8	22.4	13.1	11.9	1.2	14.4	3.3	3.8	28.1
Miller Mountain Male	2.7	21.0	18.0	12.9	2.5	13.5	4.7	1.4	23.3
Timbered Rock Female	0.0	19.4	4.0	2.9	5.8	39.0	12.6	10.3	6.0
Timbered Rock Male	0.0	10.9	5.4	1.2	2.5	37.3	19.5	17.0	6.2
Upper Timber Male	0.0	23.7	4.6	4.9	2.3	40.4	11.4	12.7	0.0
Outside Fire									
Hungry Elk Female	0.0	11.0	28.1	0.2	0.0	53.6	4.2	1.9	1.2
Hungry Elk Male	0.0	9.6	36.4	0.5	0.0	47.6	3.4	1.6	0.9
Louis Creek Female	0.2	33.1	6.7	0.0	0.0	58.0	0.0	0.0	2.1
Louis Creek Male	0.5	39.3	17.0	0.0	0.0	43.2	0.0	0.0	0.0
Lower Morine Female	2.1	7.6	10.3	0.0	0.0	80.0	0.0	0.0	0.0
Lower Morine Male	0.0	5.4	11.3	0.0	0.0	83.2	0.0	0.0	0.0
Oliver Springs Male	0.0	42.9	16.7	0.0	0.0	36.6	2.6	0.0	1.2
South Boundary Female	0.0	49.4	17.0	0.0	0.0	31.1	1.6	0.0	0.9
South Boundary Male	0.0	33.8	15.7	0.0	0.0	50.5	0.0	0.0	0.0
Yale Creek Female	4.8	20.0	37.6	0.0	0.0	37.7	0.0	0.0	0.0

Appendix J. Continued…

	Non-Breeding Season Home Range								
	Cover Type								
Owl	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Inside Fire									
Alco Rock Female	0.0	26.0	15.4	1.6	2.5	40.9	5.3	3.5	4.8
Alco Rock Male	0.0	38.7	3.4	3.7	5.5	25.6	9.9	6.0	7.3
Flat Creek Female	0.0	20.3	5.3	6.1	5.0	13.3	17.8	8.6	23.5
Flat Creek Male	0.0	23.1	4.3	8.4	4.3	20.8	8.9	4.5	25.7
Glade Creek Male	3.6	22.7	11.2	0.3	0.3	47.3	3.0	4.9	6.6
Gobblers Knob Female	0.2	33.1	17.0	1.7	2.0	23.2	9.8	3.7	9.4
Gobblers Knob Male	0.0	29.2	10.0	2.8	1.4	28.0	12.7	4.6	11.3
Hawk Creek Male	0.0	25.4	26.3	0.9	0.6	39.7	4.0	1.9	1.3
Miller Mountain Female	4.6	29.8	15.7	8.5	2.0	15.0	3.8	1.9	18.5
Miller Mountain Male	5.2	23.9	14.5	8.4	2.3	13.1	3.6	0.7	28.3
Upper Timber Female	0.0	31.2	7.2	5.9	3.0	32.0	7.8	7.8	5.1
Upper Timber Male	0.0	31.6	8.4	5.3	3.0	34.8	5.6	10.1	1.3
Outside Fire									
Hungry Elk Female	0.4	13.7	21.0	1.1	0.0	57.4	1.0	2.5	2.9
Hungry Elk Male	0.2	7.2	16.7	0.4	0.0	69.4	0.7	1.7	3.7
Louis Creek Female	3.7	29.6	26.7	0.0	0.0	40.0	0.0	0.0	0.1
Louis Creek Male	1.9	26.2	31.9	1.3	0.0	38.6	0.0	0.0	0.2
Lower Morine Female	1.1	13.3	20.7	0.0	0.0	65.0	0.0	0.0	0.0
Lower Morine Male	2.1	21.6	24.7	0.0	0.0	51.7	0.0	0.0	0.0
Oliver Springs Male	0.0	41.7	16.4	0.1	0.0	39.6	0.5	0.3	1.3
South Boundary Male	0.0	34.1	12.1	1.1	0.0	36.4	1.0	1.4	13.8
Yale Creek Female	3.4	13.4	41.7	0.0	0.0	41.5	0.0	0.0	0.0

Appendix K. Graph of dates individual northern spotted owls were monitored from September 2004 to August 2006, at the Timbered Rock and Quartz Fires, Oregon, USA. Lines indicate dates owls were monitored. Gaps indicate times when no telemetry data were



Appendix L. Percent of spotted owls inside and outside fire boundaries using cover types less than, greater than, or in proportion to availability at the Timbered Rock and Quartz Fires, based on the Neu et al. (1974) method.

Annual Habitat Use

Group	Cover Type								
	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Owls Inside the Fire (*n* = 10)									
% < Expected	20	70	40	0	70	0	20	0	80
% = Expected	30	30	60	100	30	40	80	100	20
% > Expected	0	0	0	0	0	60	0	0	0
Not Available	50	0	0	0	0	0	0	0	0
Owls Outside the Fire (*n* = 10)									
% < Expected	60	50	30	60	20	0	20	40	40
% = Expected	20	50	60	10	0	30	30	0	30
% > Expected	0	0	10	0	0	70	0	0	0
Not Available	20	0	0	30	80	0	50	60	30

Breeding Season Habitat Use

Group	Cover Type								
	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Owls Inside the Fire (*n* = 12)									
% < Expected	25	50	33	17	75	0	25	17	67
% = Expected	17	50	67	83	25	50	75	83	33
% > Expected	0	0	0	0	0	50	0	0	0
Not Available	58	0	0	0	0	0	0	0	0
Owls Outside the Fire (*n* = 11)									
% < Expected	27	45	18	36	27	0	18	27	45
% = Expected	18	55	73	0	0	64	27	0	9
% > Expected	0	0	9	0	0	36	0	0	0
Not Available	55	0	0	64	73	0	55	73	45

Appendix L. Continued…

Non-Breeding Season Habitat Use									
	Cover Type								
Group	Non	Early	RFLow	RFMod	RFHigh	NRFLow	NRFMod	NRFHigh	Salvage
Owls Inside the Fire (*n* = 12)									
% < Expected	25	17	17	8	42	0	17	8	50
% = Expected	17	83	83	83	58	58	83	92	50
% > Expected	0	0	0	8	0	42	0	0	0
Not Available	58	0	0	0	0	0	0	0	0
Owls Outside the Fire (*n* = 10)									
% < Expected	80	10	20	70	20	0	40	50	40
% = Expected	10	90	80	10	0	60	10	0	40
% > Expected	0	0	0	0	0	40	0	0	0
Not Available	10	0	0	20	80	0	50	50	20

Appendix M1. Model selection results for post-fire landscape scale habitat selection of all northern spotted owls regardless of residency status at the Timbered Rock Fire, Oregon, USA.

Model	AIC	ΔAIC	Weight
Nonhabitat[a] RFLow[b] RFMod[c] RFHigh[d] NRFLow[e] NRFMod[f] NRFHigh[g] Salvage[h] Stream[i] Road[j] Elevation[k] Aspect[l] Hardedge[m]	11059.689	0.000	1.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect Hardedge	11101.231	41.542	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Aspect Hardedge	11103.426	43.737	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect	11113.222	53.533	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Hardedge	11124.208	64.519	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Aspect	11132.919	73.230	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Hardedge	11143.213	83.524	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Aspect	11149.416	89.727	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect	11150.745	91.056	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Aspect	11161.381	101.692	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Hardedge	11161.508	101.819	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Hardedge	11162.266	102.577	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Aspect	11162.497	102.808	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Hardedge	11172.815	113.126	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Hardedge	11173.946	114.257	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation	11174.128	114.439	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road	11192.410	132.721	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation	11206.257	146.568	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation	11208.029	148.340	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road	11217.478	157.789	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road	11219.119	159.430	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream	11318.550	258.861	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream	11354.648	294.959	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream	11356.172	296.483	0.000
Hardedge Road Elevation Aspect Stream	11726.913	667.224	0.000

Appendix M1 continued…

Table continued from previous page.

Model	AIC	ΔAIC	Weight
Stream Road Aspect	11738.510	678.821	0.000
Stream Road	11748.554	688.865	0.000
Stream Road Elevation	11748.911	689.222	0.000
Hardedge Elevation Stream	11789.377	729.688	0.000
Hardedge Stream	11789.812	730.123	0.000
Stream	11817.870	758.181	0.000
Stream Elevation	11817.872	758.183	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage	12677.441	1617.752	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage	12689.518	1629.829	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh	12691.416	1631.727	0.000
RFLow RFMod NRFLow NRFMod High Salvage	12701.463	1641.774	0.000
RFLow RFMod NRFLow NRFMod High	12703.361	1643.672	0.000
RFLow RFMod NRFLow NRFMod	12725.350	1665.661	0.000
RF[n] NRF[o] High[p] Salvage	12818.389	1758.700	0.000
RF NRF High	12820.287	1760.598	0.000
Non RF NRF	12824.849	1765.160	0.000
NRFLow NRFMod	12827.537	1767.848	0.000
RF NRF	12842.276	1782.587	0.000
NRF	12842.721	1783.032	0.000
RFLow NRFLow	12955.940	1896.251	0.000
NRFLow	12979.819	1920.130	0.000
Road	13049.233	1989.544	0.000
Non Suitable	13092.162	2032.473	0.000
Low[q] Moderate[r] High Salvage	13112.865	2053.176	0.000
Low Moderate	13130.193	2070.504	0.000
Low Moderate High	13132.162	2072.473	0.000
Elevation	13260.464	2200.775	0.000
Low	13289.225	2229.536	0.000
Aspect	13321.859	2262.170	0.000

Appendix M1 continued…

Table continued from previous page.

[a] Non-habitat: Non-forested areas including; water, rock outcrops and open fields.

[b] RFLow: Roosting and foraging habitat with a low/unburned severity.

[c] RFMod: Roosting and foraging habitat with a moderate severity burn.

[d] RFHigh: Roosting and foraging habitat with a high severity burn.

[e] NRFLow: Nesting, roosting and foraging habitat with a low/unburned severity.

[f] NRFMod: Nesting, roosting and foraging habitat with a moderate severity burn.

[g] NRFHigh: Nesing, roosting and foraging habitat with a high severity burn.

[h] Salvage: Areas receiving post-fire timber harvest.

[i] Stream: Distance (m) from nearest perennial stream.

[j] Road: Distance (m) from nearest road.

[k] Elevation: Elevation (m) of random/telemetry location.

[l] Aspect: Topographical position of random/telemetry location in degrees.

[m] Hardedge: Distance (m) from nearest hard edge.

[n] RF: Roosting and foraging habitat with a low/unburned or moderate severity.

[o] NRF: Nesting, roosting and foraging habitat with a low/unburned or moderate severity.

[p] High: High severity fire regardless of habitat.

[q] Low: Low severity fire regardless of habitat.

Appendix M2. Model selection results for post-fire landscape scale habitat selection of northern spotted owls residing within the boundaries of the Timbered Rock Fire, Oregon, USA.

Model	AIC	ΔAIC	Weight
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect Hardedge	7704.633	0.000	0.986
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Hardedge	7713.391	8.758	0.012
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect Hardedge	7717.293	12.660	0.002
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Hardedge	7724.912	20.279	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Aspect Hardedge	7731.618	26.985	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Hardedge	7737.823	33.190	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Hardedge	7788.122	83.489	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Hardedge	7792.019	87.386	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect	7804.724	100.091	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Hardedge	7808.695	104.062	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation	7811.972	107.339	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect	7814.655	110.022	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Aspect	7816.948	112.315	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation	7821.031	116.398	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation	7822.707	118.074	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Aspect	7883.786	179.153	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Aspect	7886.421	181.788	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road	7887.687	183.054	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road	7890.034	185.401	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Aspect	7891.042	186.409	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road	7893.993	189.360	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream	7992.092	287.459	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream	7998.916	294.283	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream	8002.187	297.554	0.000
Stream Road Elevation Hardedge	8141.284	436.651	0.000

Appendix M2 continued…

Table continued from previous page.

Model	AIC	ΔAIC	Weight
Hardedge Elevation Stream	8183.967	479.334	0.000
Hardedge Stream	8195.725	491.092	0.000
Stream Road Elevation	8219.372	514.739	0.000
Stream Road	8234.305	529.672	0.000
Stream Road Aspect	8235.026	530.393	0.000
Stream Elevation	8282.987	578.354	0.000
Stream	8297.793	593.160	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage	8683.001	978.368	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage	8683.462	978.829	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh	8689.403	984.770	0.000
RFLow RFMod NRFLow NRFMod High Salvage	8697.340	992.707	0.000
RFLow RFMod NRFLow NRFMod High	8703.742	999.109	0.000
RFLow RFMod NRFLow NRFMod	8743.011	1038.378	0.000
Low Moderate High	8841.346	1136.713	0.000
Low Moderate High Salvage	8841.789	1137.156	0.000
Low Moderate	8853.863	1149.230	0.000
NRFLow NRFMod	8891.872	1187.239	0.000
Road	8894.053	1189.420	0.000
RF NRF High Salvage	8898.717	1194.084	0.000
RF NRF High	8905.119	1200.486	0.000
Elevation	8908.929	1204.296	0.000
Non RF NRF	8911.265	1206.632	0.000
NRF	8943.577	1238.944	0.000
RF NRF	8944.389	1239.756	0.000
Non Suitable	8978.969	1274.336	0.000
RFLow NRFLow	8983.921	1279.288	0.000
Hardedge	9020.257	1315.624	0.000
NRFLow	9042.729	1338.096	0.000
Low	9086.639	1382.006	0.000
Aspect	9101.165	1396.532	0.000

Appendix M3. Model selection results for post-fire landscape scale habitat selection of northern spotted owls residing outside the boundaries of the Timbered Rock Fire, Oregon, USA.

Model	AIC	ΔAIC	Weight
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect	6165.399	0.000	0.720
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect Hardedge	6167.290	1.891	0.280
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Aspect	6202.261	36.862	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect	6213.933	48.534	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Aspect Hardedge	6215.459	50.060	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation	6234.770	69.371	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Hardedge	6236.316	70.917	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Aspect	6238.843	73.444	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Aspect Hardedge	6240.817	75.418	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road	6260.956	95.557	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Hardedge	6262.620	97.221	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Aspect	6266.802	101.403	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation	6281.322	115.923	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Elevation Hardedge	6282.384	116.985	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream	6287.515	122.116	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Aspect	6292.478	127.079	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation	6311.873	146.474	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Elevation Hardedge	6313.718	148.319	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road	6321.112	155.713	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream Road Hardedge	6322.347	156.948	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road	6352.117	186.718	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream Road Hardedge	6354.030	188.631	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage Stream	6359.053	193.654	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Stream	6388.478	223.079	0.000
Hardedge Road Elevation Aspect Stream	6721.988	556.589	0.000
Stream Road Elevation Hardedge	6748.074	582.675	0.000
Hardedge Elevation Stream	6761.725	596.326	0.000

Appendix M3 continued…

Table continued from previous page.

Model	AIC	ΔAIC	Weight
Stream Road Elevation	6788.961	623.562	0.000
Stream Elevation	6790.009	624.610	0.000
Stream Road Hardedge	6860.718	695.319	0.000
Hardedge Stream	6886.103	720.704	0.000
Stream Road Aspect	6899.837	734.438	0.000
Stream Road	6908.398	742.999	0.000
Stream	6915.928	750.529	0.000
Nonhabitat RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage	7143.415	978.016	0.000
RFLow RFMod NRFLow NRFMod High Salvage	7173.321	1007.922	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh Salvage	7175.321	1009.922	0.000
RFLow RFMod NRFLow NRFMod High	7207.603	1042.204	0.000
RFLow RFMod RFHigh NRFLow NRFMod NRFHigh	7209.603	1044.204	0.000
RF NRF High Salvage	7210.137	1044.738	0.000
Non RF NRF	7210.272	1044.873	0.000
RFLow RFMod NRFLow NRFMod	7214.476	1049.077	0.000
RFLow NRFLow	7220.331	1054.932	0.000
RF NRF High	7244.419	1079.020	0.000
NRFLow	7245.332	1079.933	0.000
NRFLow NRFMod	7246.376	1080.977	0.000
RF NRF	7251.292	1085.893	0.000
NRF	7267.614	1102.215	0.000
Non Suitable	7417.835	1252.436	0.000
Low Moderate High Salvage	7524.132	1358.733	0.000
Road	7654.297	1488.898	0.000
Low Moderate High	7657.085	1491.686	0.000
Low Moderate	7676.631	1511.232	0.000
Hardedge	7696.716	1531.317	0.000
Low	7698.745	1533.346	0.000
Aspect	7708.509	1543.110	0.000
Elevation	7741.825	1576.426	0.000

Appendix N. Model selection results displaying the top model and any competing models for year round, post-fire home range scale habitat selection of individual owls, evaluated with logistic regression at the Timbered Rock and Quartz fires, Oregon USA.

Owl	Model	AIC	ΔAIC	Weight
Alco Rock ♀	Distance-p[a] NRFLow*Distance[b] NRFLow[c] Stream[d]	775.111	0.000	0.135
	Distance-p NRFLow*Distance NRFLow Stream Hardedge[e]	775.134	0.023	0.134
	Distance-p NRFLow*Distance NRFLow Stream Elevation[f]	776.482	1.371	0.068
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge Stream	776.558	1.447	0.066
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance[g] NRFMod[h] Stream Hardedge	776.830	1.719	0.057
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance NRFMod Stream	777.037	1.926	0.052
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance NRFMod Elevation Hardedge Stream	777.948	2.837	0.033
Alco Rock ♂	Distance-p Stream	725.743	0.000	0.096
	Distance-p NRFLow Stream	726.348	0.605	0.071
	Distance-p Non-suitable[i] Suitable[j] Stream	726.685	0.942	0.060
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance NRFMod Stream	727.018	1.275	0.051
	Distance-p RFLow[k] NRFLow Stream	727.443	1.700	0.041
	Distance-p Stream Elevation	727.620	1.877	0.038
	Distance-p Hardedge Stream	727.660	1.917	0.037
	Distance-p NRFLow*Distance NRFLow Stream	727.702	1.959	0.036
	Distance-p NRFLow Hardedge Stream	727.721	1.978	0.036
	Distance-p NRFLow NRFMod Stream	727.844	2.101	0.034
Flat Creek ♀	Distance-p NRFLow*Distance NRFLow Elevation	855.074	0.000	0.180
	Distance-p NRFLow*Distance NRFLow	856.002	0.928	0.113
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge	856.604	1.530	0.084
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance NRFMod Elevation	856.640	1.566	0.082
	Distance-p NRFLow*Distance NRFLow Stream Elevation	857.047	1.973	0.067
	Distance-p NRFLow*Distance NRFLow Stream	857.337	2.263	0.058
Flat Creek ♂	Distance-p Non-suitable Suitable Stream	718.797	0.000	0.227
	Distance-p Non-suitable Suitable Stream Elevation	720.640	1.843	0.090
	Distance-p Non-suitable Suitable Elevation	720.684	1.887	0.088
	Distance-p Non-suitable Suitable Hardedge Stream	720.790	1.993	0.084
	Distance-p RFLow RFMod[l] NRFLow NRFMod High[m] Stream	721.601	2.804	0.056

Appendix N continued…

Owl	Model	AIC	ΔAIC	Weight
Table continued from previous page.				
Glade Creek ♂	Distance-p NRF[n]	684.996	0.000	0.137
	Distance-p NRFLow NRFMod Hardedge	685.857	0.861	0.089
	Distance-p RF[o] NRF	686.852	1.856	0.054
	Distance-p NRFLow NRFMod	686.913	1.917	0.053
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance Hardedge	687.429	2.433	0.041
Gobblers Knob ♀	Distance-p RFLow RFMod NRFLow NRFMod Stream	922.697	0.000	0.138
	Distance-p RFLow RFMod NRFLow NRFMod High Stream	923.708	1.011	0.083
	Distance-p RFLow RFMod NRFLow NRFMod Stream Elevation	923.761	1.064	0.081
	Distance-p RFLow RFMod NRFLow NRFMod High Stream Elevation	924.172	1.475	0.066
	Distance-p RFLow RFMod NRFLow NRFMod Elevation	924.626	1.929	0.053
	Distance-p RFLow NRFLow Stream	924.652	1.955	0.052
	Distance-p RFLow RFMod NRFLow NRFMod Elevation	924.673	1.976	0.051
	Distance-p RFLow RFMod NRFLow NRFMod Hardedge Stream	924.693	1.996	0.051
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance Stream	925.151	2.454	0.040
Gobblers Knob ♂	Distance-p RFLow RFMod NRFLow NRFMod High Elevation Hardedge	901.630	0.000	0.183
	Distance-p RFLow RFMod NRFLow NRFMod High Elevation Hardedge Stream	902.697	1.067	0.107
	Distance-p RFLow RFMod NRFLow NRFMod Elevation Hardedge	903.074	1.444	0.089
	Distance-p RFLow RFMod NRFLow NRFMod High Hardedge Stream	903.190	1.560	0.084
	Distance-p RFLow RFMod NRFLow NRFMod Hardedge Stream	903.292	1.662	0.080
	Distance-p RFLow RFMod NRFLow NRFMod Elevation Hardedge Stream	903.922	2.292	0.058
Hungry Elk ♀	Distance-p Non-suitable Suitable Hardedge Stream	771.555	0.000	0.262
	Distance-p Non-suitable Suitable Stream	772.122	0.567	0.197
	Distance-p Non-suitable Suitable Elevation Hardedge Stream	773.551	1.996	0.096
	Distance-p Non-suitable Suitable Stream Elevation	773.845	2.290	0.083

Appendix N continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Hungry Elk ♂	Distance-p Elevation	617.690	0.000	0.095
	Distance-p Non-suitable Suitable Elevation	618.212	0.522	0.073
	Distance-p NRFLow NRFMod Elevation	618.570	0.880	0.061
	Distance-p RFLow NRFLow Elevation	618.756	1.066	0.056
	Distance-p RFLow RFMod NRFLow NRFMod Elevation	619.204	1.514	0.044
	Distance-p RFLow NRFLow Elevation Hardedge	619.204	1.514	0.044
	Distance-p NRFLow Elevation	619.320	1.630	0.042
	Distance-p Non-suitable Suitable Elevation Hardedge	619.616	1.926	0.036
	Distance-p RFLow RFMod NRFLow NRFMod High Elevation	619.834	2.144	0.032
Louis Creek ♀	Distance-p NRFLow*Distance NRFLow Elevation Hardedge	736.462	0.000	0.093
	Distance-p NRFLow*Distance NRFLow Hardedge	737.190	0.728	0.065
	Distance-p Hardedge	737.260	0.798	0.062
	Distance-p Aspect[p]	737.663	1.201	0.051
	Distance-p	737.798	1.336	0.048
	Distance-p Elevation	738.019	1.557	0.043
	Distance-p Hardedge Stream	738.098	1.636	0.041
	Distance-p NRFLow*Distance NRFLow Stream Hardedge	738.113	1.651	0.041
	Distance-p NRFLow*Distance NRFLow Elevation	738.116	1.654	0.041
	Distance-p NRFLow*Distance NRFLow	738.371	1.909	0.036
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge Stream	738.420	1.958	0.035
	Distance-p Stream	738.551	2.089	0.033
Louis Creek ♂	Distance-p NRFLow*Distance NRFLow Elevation Hardedge	844.839	0.000	0.346
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge Stream	846.685	1.846	0.137
	Distance-p NRFLow*Distance NRFLow Hardedge	847.024	2.185	0.116

Appendix N continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Lower Morine ♀	Distance-p NRFLow*Distance NRFLow Elevation	708.220	0.000	0.154
	Distance-p NRFLow Elevation	708.389	0.169	0.142
	Distance-p Elevation	708.449	0.229	0.138
	Distance-p Non-suitable Suitable Elevation	709.927	1.707	0.066
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge	710.053	1.833	0.062
	Distance-p Stream Elevation	710.098	1.878	0.060
	Distance-p NRFLow*Distance NRFLow Stream Elevation	710.166	1.946	0.058
	Distance-p NRFLow Elevation Hardedge	710.294	2.074	0.055
Lower Morine ♂	Distance-p Stream	649.815	0.000	0.187
	Distance-p Stream Elevation	650.738	0.923	0.118
	Distance-p NRFLow Stream	651.355	1.540	0.087
	Distance-p Non-suitable Suitable Stream	651.470	1.655	0.082
	Distance-p Hardedge Stream	651.783	1.968	0.070
	Distance-p NRFLow Stream Elevation	651.839	2.024	0.068
Miller Mountain ♀	Distance-l NRFLow Elevation Hardedge	923.841	0.000	0.174
	Distance-l NRFLow Elevation Hardedge Stream	924.836	0.995	0.106
	Distance-l NRFLow NRFMod Elevation Hardedge	925.025	1.184	0.096
	Distance-l NRFLow*Distance NRFLow elevation hardedge	925.568	1.727	0.073
	Distance-l RFLow NRFLow Elevation Hardedge	925.655	1.814	0.070
	Distance-l NRFLow NRFMod Elevation Hardedge Stream	925.840	1.999	0.064
	Distance-l RFLow NRFLow Elevation Hardedge Stream	926.569	2.728	0.044
Miller Mountain ♂	Distance-p Non-suitable Suitable Elevation	830.064	0.000	0.248
	Distance-p Non-suitable Suitable Elevation Hardedge	830.953	0.889	0.159
	Distance-p Non-suitable Suitable Stream Elevation	832.063	1.999	0.091
	Distance-p RFLow NRFLow Elevation	832.524	2.460	0.072

Appendix N continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Oliver Springs ♂	Distance-p Non-suitable Suitable Elevation	746.045	0.000	0.071
	Distance-p Non-suitable Suitable Stream	746.798	0.753	0.049
	Distance-p Non-suitable Suitable Elevation Hardedge	746.939	0.894	0.045
	Distance-p Non-suitable Suitable Hardedge Stream	747.513	1.468	0.034
	Distance-p Non-suitable Suitable Road[q]	747.639	1.594	0.032
	Distance-p Road	747.687	1.642	0.031
	Distance-p Non-suitable Suitable	747.717	1.672	0.031
	Distance-p Aspect	747.736	1.691	0.030
	Distance-p Stream	747.754	1.709	0.030
	Distance-p	747.798	1.753	0.030
	Distance-p Non-suitable Suitable Stream Elevation	747.918	1.873	0.028
	Distance-p Non-suitable Suitable Hardedge	747.978	1.933	0.027
	Distance-p Elevation	748.034	1.989	0.026
	Distance-p Hardedge	748.211	2.166	0.024
South Boundary ♀	Distance-p Elevation	654.491	0.000	0.086
	Distance-p NRFLow*Distance NRFLow Elevation	654.964	0.473	0.068
	Distance-p NRFLow Elevation	655.003	0.512	0.066
	Distance-p Stream Elevation	656.489	1.998	0.032
	Distance-p	656.675	2.184	0.029
South Boundary ♂	Distance-p NRFLow*Distance NRFLow Hardedge	771.303	0.000	0.099
	Distance-p NRFLow*Distance NRFLow	771.349	0.046	0.097
	Distance-p NRFLow*Distance NRFLow Road	771.819	0.516	0.076
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge	772.450	1.147	0.056
	Distance-p NRFLow*Distance NRFLow Stream	772.524	1.221	0.054
	Distance-p NRFLow*Distance NRFLow Stream Hardedge	772.652	1.349	0.050
	Distance-p NRFLow*Distance NRFLow Elevation	772.798	1.495	0.047
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance NRFMod Hardedge	774.194	2.891	0.023

Appendix N continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Upper Timber ♂	Distance-p RFLow RFMod NRFLow NRFMod Elevation	528.872	0.000	0.157
	Distance-l RFLow RFMod NRFLow NRFMod Elevation	529.859	0.987	0.096
	Distance-p RFLow RFMod NRFLow NRFMod Stream Elevation	530.724	1.852	0.062
	Distance-p RFLow RFMod NRFLow NRFMod Elevation Hardedge	530.802	1.930	0.060
	Distance-p RFLow RFMod NRFLow NRFMod High Elevation	530.869	1.997	0.058
	Distance-l RFLow RFMod NRFLow NRFMod Stream Elevation	531.817	2.945	0.036
Yale Creek ♀	Distance-p Road	624.663	0.000	0.071
	Distance-p Hardedge Stream	624.774	0.111	0.067
	Distance-p Stream	624.969	0.306	0.061
	Distance-p	625.269	0.606	0.052
	Distance-p NRFLow*Distance NRFLow	625.746	1.083	0.041
	Distance-p Hardedge	625.819	1.156	0.040
	Distance-p NRFLow*Distance NRFLow Road	625.859	1.196	0.039
	Distance-p Non-suitable Suitable Road	625.980	1.317	0.037
	Distance-p Non-suitable Suitable	625.984	1.321	0.037
	Distance-p Non-suitable Suitable Stream	626.089	1.426	0.035
	Distance-p NRFLow*Distance NRFLow Stream	626.282	1.619	0.031
	Distance-p Non-suitable Suitable Hardedge Stream	626.476	1.813	0.029
	Distance-p NRFLow Road	626.577	1.914	0.027
	Distance-p NRFLow Hardedge Stream	626.711	2.048	0.025

[a] Distance-p,l: Distance from site center function representing a thrid order polynomial (p) or a linear distance function (l).

[b] NRFLow*Distance: Interaction term between distance from site center and NRFLow habitat.

[c] NRFLow: Nesting, roosting and foraging habitat with a low/unburned severity.

[d] Stream: Distance (m) from nearest perennial stream.

[e] Hardedge: Distance (m) from nearest hard edge.

[f] Elevation: Elevation (m) of random/telemetry location.

[g] NRFMod*Distance: Interaction term between distance from site center and NRFMod habitat.

[h] NRFMod: Nesting, roosting and foraging habitat with a moderate burn severity.

[i] Non-suitable: Combination of non-habitat, high severity fire and salvage logged areas.

Appendix N continued…

Table continued from previous page.

[j] Suitable: Combination of RF and NRF habitats with a low/unburned or moderated severity burn.

[k] RFLow: Roosting and foraging habitat with a low/unburned severity.

[l] RFMod: Roosting and foraging habitat with a moderate severity burn.

[m] High: High severity burn regardless of habitat.

[n] NRF: Nesting, roosting and foraging habitat with a low/unburned or moderate severity burn.

[o] RF: Roosting and foraging habitat with a low/unburned of moderate severity burn.

[p] Aspect: Position of telemetry/random location in degrees.

[q] Road: Distance (m) from nearest road.

Appendix O. Model selection results displaying the top model and any competing models for breeding season, post-fire home range scale habitat selection of individual owls, evaluated with logistic regression at the Timbered Rock and Quartz fires, Oregon USA.

Owl	Model	AIC	ΔAIC	Weight
Alco Rock ♀	Distance-p NRFLow NRFMod Road	482.645	0.000	0.280
	Distance-p Road	483.361	0.716	0.196
	Distance-p NRFLow Road	483.442	0.797	0.188
	Distance-p RFLow NRFLow Road	485.392	2.747	0.071
Alco Rock ♂	Distance-p Hardedge	472.883	0.000	0.170
	Distance-p Hardedge Stream	473.511	0.628	0.125
	Distance-p NRFLow Hardedge	474.868	1.985	0.063
	Distance-p NRFLow Hardedge Stream	475.487	2.604	0.046
Flat Creek ♀	Distance-p NRFLow*Distance NRFLow Stream Hardedge	438.438	0.000	0.050
	Distance-p NRFLow	438.637	0.199	0.045
	Distance-p Non-suitable Suitable	438.737	0.299	0.043
	Distance-p RF NRF	438.972	0.534	0.038
	Distance-p RFLow NRFLow	439.392	0.954	0.031
	Distance-p Non-suitable Suitable Hardedge	439.616	1.178	0.028
	Distance-p NRFLow*Distance NRFLow NRFMod*Distance NRFMod Stream Hardedge	439.883	1.445	0.024
	Distance-p Non-suitable Suitable Stream	439.954	1.516	0.023
	Distance-p RFLow RFMod NRFLow NRFMod	439.982	1.544	0.023
	Distance-p Non-suitable Suitable Elevation	440.273	1.835	0.020
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge	440.283	1.845	0.020
	Distance-p NRFLow Stream	440.327	1.889	0.019
	Distance-p NRFLow*Distance NRFLow Elevation	440.371	1.933	0.019
	Distance-p NRFLow*Distance NRFLow Elevation Hardedge Stream	440.372	1.934	0.019
	Distance-p NRF	440.379	1.941	0.019
	Distance-p NRFLow*Distance NRFLow Road	440.380	1.942	0.019
	Distance-p	440.413	1.975	0.019
	Distance-p NRFLow Road	440.435	1.997	0.018
	Distance-p NRFLow Elevation	440.440	2.002	0.018

Appendix O continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Flat Creek ♂	Distance-p RF NRF High Salvage	459.778	0.000	0.130
	Distance-p RFLow RFMod NRFLow NRFMod High Stream	460.721	0.943	0.081
	Distance-p Non-suitable Suitable Stream	460.798	1.020	0.078
	Distance-p RF NRF	460.926	1.148	0.073
	Distance-p Non-suitable Suitable	461.079	1.301	0.068
	Distance-p RFLow RFMod NRFLow NRFMod High	461.560	1.782	0.053
	Distance-p Non-suitable Suitable Hardedge Stream	462.481	2.703	0.034
Glade Creek ♂	Distance-p NRFLow Hardedge	435.624	0.000	0.107
	Distance-p NRFLow*Distance NRFLow Hardedge	436.612	0.988	0.065
	Distance-p Hardedge	436.794	1.170	0.060
	Distance-p NRFLow NRFMod Hardedge	437.267	1.643	0.047
	Distance-p RFLow NRFLow Hardedge	437.311	1.687	0.046
	Distance-p NRFLow Hardedge Stream	437.317	1.693	0.046
	Distance-p NRFLow Elevation Hardedge	437.470	1.846	0.043
	Distance-p Hardedge Stream	437.558	1.934	0.041
	Distance-p Non-suitable Suitable Hardedge	438.099	2.475	0.031
Gobblers Knob ♀	Distance-p Stream	547.273	0.000	0.067
	Distance-p Aspect	547.303	0.030	0.066
	Distance-p	547.830	0.557	0.050
	Distance-p RFLow NRFLow Stream	548.281	1.008	0.040
	Distance-p Road	548.752	1.479	0.032
	Distance-p Elevation	548.945	1.672	0.029
	Distance-p Stream Elevation	549.180	1.907	0.026
	Distance-p NRFLow Stream	549.180	1.907	0.026
	Distance-p Hardedge Stream	549.215	1.942	0.025
	Distance-p RFLow NRFLow	549.264	1.991	0.025
	Distance-p RFLow RFMod NRFLow NRFMod Stream	549.357	2.084	0.023

Appendix O continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Gobblers Knob ♂	Distance-p Low	538.272	0.000	0.152
	Distance-p RF NRF	539.818	1.546	0.070
	Distance-p Low Moderate	540.225	1.953	0.057
	Distance-p Aspect	540.929	2.657	0.040
Hungry Elk ♀	Distance-p Elevation	526.213	0.000	0.101
	Distance-p NRFLow Elevation	527.321	1.108	0.058
	Distance-p Stream	527.370	1.157	0.056
	Distance-p Stream Elevation	527.400	1.187	0.056
	Distance-p NRFLow Stream	527.537	1.324	0.052
	Distance-p NRFLow NRFMod Elevation	527.928	1.715	0.043
	Distance-p NRFLow Stream Elevation	528.237	2.024	0.037
Hungry Elk ♂	Distance-p Road	506.467	0.000	0.388
	Distance-p NRFLow Road	508.240	1.773	0.160
	Distance-p Non-suitable Suitable Road	508.993	2.526	0.110
Louis Creek ♀	Distance-p Aspect	411.946	0.000	0.160
	Distance-p Hardedge	413.038	1.092	0.092
	Distance-p Road	413.731	1.785	0.065
	Distance-p Elevation	414.283	2.337	0.050
Louis Creek ♂	Distance-p Hardedge Stream	484.019	0.000	0.122
	Distance-p Hardedge	484.498	0.479	0.096
	Distance-p Stream	485.841	1.822	0.049
	Distance-p Non-suitable Suitable Hardedge Stream	485.881	1.862	0.048
	Distance-p NRFLow Hardedge Stream	486.007	1.988	0.045
	Distance-p Non-suitable Suitable Hardedge	486.029	2.010	0.045

Appendix O continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Lower Morine ♀	Distance-p NRFLow Elevation	532.342	0.000	0.239
	Distance-p NRFLow*Distance NRFLow Elevation	532.996	0.654	0.173
	Distance-p RFLow NRFLow Elevation	534.202	1.860	0.094
	Distance-p NRFLow Stream Elevation	534.288	1.946	0.090
	Distance-p NRFLow Elevation Hardedge	534.338	1.996	0.088
	Distance-p NRFLow*Distance NRFLow Stream Elevation	534.949	2.607	0.065
Lower Morine ♂	Distance-p Stream	525.297	0.000	0.114
	Distance-p Stream Elevation	525.767	0.470	0.090
	Distance-p Hardedge Stream	525.794	0.497	0.089
	Distance-p NRFLow Hardedge Stream	526.408	1.111	0.065
	Distance-p Elevation	526.789	1.492	0.054
	Distance-p NRFLow Stream	526.935	1.638	0.050
	Distance-p Non-suitable Suitable Stream	526.938	1.641	0.050
	Distance-p Non-suitable Suitable Hardedge Stream	526.990	1.693	0.049
	Distance-p NRFLow Stream Elevation	527.028	1.731	0.048
	Distance-p Non-suitable Suitable Stream Elevation	527.172	1.875	0.045
	Distance-p NRFLow Elevation	527.488	2.191	0.038
Miller Mountain ♀	Distance-p Non-suitable Suitable Hardedge	530.490	0.000	0.085
	Distance-p Non-suitable Suitable Road	530.531	0.041	0.083
	Distance-p Non-suitable Suitable Elevation Hardedge	530.762	0.272	0.074
	Distance-p RFLow RFMod NRFLow NRFMod High Road	530.811	0.321	0.072
	Distance-p Road	531.093	0.603	0.063
	Distance-p NRFLow Road	531.219	0.729	0.059
	Distance-p Non-suitable Suitable Hardedge Stream	531.614	1.124	0.048
	Distance-p Non-suitable Suitable Elevation Hardedge Stream	532.631	2.141	0.029

Appendix O continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Miller Mountain ♂	Distance-p Low	468.913	0.000	0.081
	Distance-p RF NRF	470.199	1.286	0.043
	Distance-p Low Moderate	470.710	1.797	0.033
	Distance-p Non-suitable Suitable Elevation	470.747	1.834	0.032
	Distance-p Elevation	470.829	1.916	0.031
	Distance-p NRFLow Elevation	471.090	2.177	0.027
Oliver Springs ♂	Distance-p RFLow NRFLow Stream	524.974	0.000	0.112
	Distance-p Non-suitable Suitable Stream	525.426	0.452	0.089
	Distance-p Non-suitable Suitable Elevation	526.073	1.099	0.065
	Distance-p RFLow NRFLow Elevation	526.134	1.160	0.063
	Distance-p RFLow NRFLow Stream Elevation	526.729	1.755	0.047
	Distance-p RFLow NRFLow Hardedge Stream	526.798	1.824	0.045
	Distance-p RFLow RFMod NRFLow NRFMod Stream	526.899	1.925	0.043
	Distance-p Non-suitable Suitable Stream Elevation	526.919	1.945	0.042
	Distance-p Non-suitable Suitable Hardedge Stream	526.925	1.951	0.042
	Distance-p Non-suitable Suitable Elevation Hardedge	527.681	2.707	0.029
South Boundary ♀	Distance-p Aspect	528.285	0.000	0.116
	Distance-p	528.516	0.231	0.103
	Distance-p Road	529.306	1.021	0.070
	Distance-p Low	530.144	1.859	0.046
	Distance-p NRF	530.391	2.106	0.040

Appendix O continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
South Boundary ♂	Distance-p NRFLow	537.917	0.000	0.077
	Distance-p NRF	538.059	0.142	0.072
	Distance-p RFLow NRFLow	538.705	0.788	0.052
	Distance-p RF NRF	538.863	0.946	0.048
	Distance-p Non-suitable Suitable	539.069	1.152	0.043
	Distance-p NRFLow Elevation	539.372	1.455	0.037
	Distance-p NRFLow Road	539.400	1.483	0.037
	Distance-p NRFLow Hardedge	539.705	1.788	0.031
	Distance-p NRFLow Stream	539.761	1.844	0.031
	Distance-p NRFLow NRFMod	539.804	1.887	0.030
	Distance-p NRFLow*Distance NRFLow	539.910	1.993	0.028
	Distance-p RFLow NRFLow Elevation	539.914	1.997	0.028
	Distance-p Non-suitable Suitable Elevation	540.142	2.225	0.025
Timbered Rock ♀	Distance-l RFLow RFMod NRFLow NRFMod High Elevation Hardedge Stream	327.227	0.000	0.094
	Distance-l NRFLow Elevation	327.578	0.351	0.079
	Distance-l NRFLow NRFMod Elevation	328.348	1.121	0.054
	Distance-l NRFLow Stream Elevation	328.474	1.247	0.050
	Distance-l NRFLow*Distance NRFLow Elevation	328.522	1.295	0.049
	Distance-l NRFLow Stream	328.912	1.685	0.040
	Distance-l NRFLow Elevation Hardedge	329.450	2.223	0.031
Timbered Rock ♂	Distance-l NRFLow Hardedge Stream	269.198	0.000	0.147
	Distance-l NRFLow*Distance NRFLow Stream Hardedge	269.252	0.054	0.143
	Distance-l RFLow NRFLow Hardedge Stream	270.585	1.387	0.073
	Distance-l NRFLow Elevation Hardedge Stream	271.180	1.982	0.054
	Distance-l NRFLow NRFMod Hardedge Stream	271.198	2.000	0.054
	Distance-l NRFLow*Distance NRFLow Elevation Hardedge Stream	271.241	2.043	0.053

Appendix O continued…

Owl	Model	AIC	ΔAIC	Weight
Table continued from previous page.				
Yale Creek ♀	Distance-p NRFLow*Distance NRFLow	359.278	0.000	0.077
	Distance-p NRFLow*Distance NRFLow Stream	359.981	0.703	0.054
	Distance-p Stream	360.051	0.773	0.053
	Distance-p NRFLow*Distance NRFLow Elevation	360.136	0.858	0.050
	Distance-p Non-suitable Suitable	360.342	1.064	0.045
	Distance-p Hardedge Stream	360.412	1.134	0.044
	Distance-p Non-suitable Suitable Stream	360.704	1.426	0.038
	Distance-p	360.818	1.540	0.036
	Distance-p NRFLow*Distance NRFLow Hardedge	361.049	1.771	0.032
	Distance-p NRFLow*Distance NRFLow Road	361.049	1.771	0.032
	Distance-p Elevation	361.197	1.919	0.030
	Distance-p Hardedge	361.216	1.938	0.029
	Distance-p NRFLow*Distance NRFLow Stream Hardedge	361.508	2.230	0.025

Appendix P. Model selection results displaying the top model and any competing models for non-breeding season, post-fire home range scale habitat selection of individual owls, evaluated with logistic regression at the Timbered Rock and Quartz fires, Oreg

Owl	Model	AIC	ΔAIC	Weight
Alco Rock ♀	NRFLow NRFMod Hardedge Stream	545.062	0.000	0.117
	NRFLow NRFMod Stream	545.517	0.455	0.093
	NRFLow Hardedge Stream	545.705	0.643	0.085
	NRFLow Stream	545.954	0.892	0.075
	NRFLow NRFMod Elevation Hardedge Stream	546.564	1.502	0.055
	RFLow NRFLow Hardedge Stream	546.619	1.557	0.054
	RFLow NRFLow Stream	546.677	1.615	0.052
	NRFLow NRFMod Stream Elevation	546.861	1.799	0.048
	RFLow RFMod NRFLow NRFMod Hardedge Stream	546.979	1.917	0.045
	RFLow RFMod NRFLow NRFMod Stream	547.320	2.258	0.038
Alco Rock ♂	Hardedge Stream	489.581	0.000	0.288
	NRFLow Hardedge Stream	490.915	1.334	0.148
	Non-suitable Suitable Hardedge Stream	491.132	1.551	0.133
	NRFLow NRFMod Hardedge Stream	492.266	2.685	0.075
Flat Creek ♀	NRFLow NRFMod Elevation Hardedge	616.934	0.000	0.224
	NRFLow NRFMod Elevation	617.947	1.013	0.135
	NRFLow Elevation Hardedge	618.311	1.377	0.113
	NRFLow NRFMod Elevation Hardedge Stream	618.347	1.413	0.111
	NRFLow NRFMod Stream Elevation	619.476	2.542	0.063
Flat Creek ♂	Non-suitable Suitable Elevation	511.203	0.000	0.210
	RFLow RFMod NRFLow NRFMod Elevation	512.765	1.562	0.096
	Non-suitable Suitable Elevation Hardedge	512.828	1.625	0.093
	Non-suitable Suitable Stream Elevation	513.201	1.998	0.077
	Non-suitable Suitable Stream	514.159	2.956	0.048

Appendix P continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Glade Creek ♂	NRFLow Elevation	414.326	0.000	0.083
	RFLow NRFLow Stream Elevation	415.046	0.720	0.058
	RFLow NRFLow	415.104	0.778	0.056
	NRFLow	415.287	0.961	0.051
	RFLow NRFLow Elevation Hardedge	415.314	0.988	0.051
	RFLow NRFLow Hardedge	415.607	1.281	0.044
	NRFLow Stream Elevation	415.644	1.318	0.043
	NRFLow Elevation Hardedge	415.701	1.375	0.042
	RFLow NRFLow Elevation	415.764	1.438	0.040
	NRFLow Hardedge	415.907	1.581	0.038
	RFLow NRFLow Elevation Hardedge Stream	416.107	1.781	0.034
	NRFLow NRFMod Elevation	416.323	1.997	0.031
	RF NRF	416.427	2.101	0.029
Gobblers Knob ♀	RFLow RFMod NRFLow NRFMod Stream	581.924	0.000	0.113
	NRFLow NRFMod Stream	582.283	0.359	0.094
	RFLow RFMod NRFLow NRFMod High Stream	582.681	0.757	0.077
	RFLow NRFLow Stream	582.927	1.003	0.068
	RFLow RFMod NRFLow NRFMod Stream Elevation	583.643	1.719	0.048
	RFLow RFMod NRFLow NRFMod Hardedge Stream	583.757	1.833	0.045
	NRFLow NRFMod Hardedge Stream	584.002	2.078	0.040
Gobblers Knob ♂	RFLow RFMod NRFLow NRFMod High Elevation Hardedge Stream	611.071	0.000	0.091
	RFLow RFMod NRFLow NRFMod High Stream Elevation	611.133	0.062	0.088
	RFLow RFMod NRFLow NRFMod High Elevation	611.463	0.392	0.075
	RFLow RFMod NRFLow NRFMod High Elevation Hardedge	611.506	0.435	0.073
	Stream Elevation	611.748	0.677	0.065
	Non-suitable Suitable Elevation Hardedge Stream	612.098	1.027	0.054
	RFLow NRFLow Elevation	612.129	1.058	0.054
	NRFLow Elevation Hardedge Stream	612.241	1.170	0.051

Appendix P continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Hawk Creek ♂	NRFLow NRFMod Stream	363.177	0.000	0.246
	NRFLow NRFMod Hardedge Stream	364.900	1.723	0.104
	NRFLow NRFMod Stream Elevation	365.174	1.997	0.091
	RFLow RFMod NRFLow NRFMod Stream	365.719	2.542	0.069
Hungry Elk ♀	Aspect	474.538	0.000	0.111
	Road	475.753	1.215	0.060
	Hardedge	475.979	1.441	0.054
	Stream	476.025	1.487	0.053
	Elevation	476.145	1.607	0.050
	Low	476.301	1.763	0.046
	NRFLow	476.352	1.814	0.045
	NRF	476.375	1.837	0.044
	NRFLow Hardedge	477.104	2.566	0.031
Hungry Elk ♂	RFLow NRFLow Elevation Hardedge Stream	429.736	0.000	0.676
	RFLow RFMod NRFLow NRFMod Elevation Hardedge Stream	433.583	3.847	0.099
Louis Creek ♀	NRFLow Road	590.980	0.000	0.509
	RFLow NRFLow Road	592.862	1.882	0.199
	NRFLow Stream	595.879	4.899	0.044
Louis Creek ♂	NRFLow Road	608.663	0.000	0.445
	RFLow NRFLow Road	610.049	1.386	0.223
	RFLow RFMod NRFLow NRFMod Road	611.259	2.596	0.122
Lower Morine ♀	Stream	356.002	0.000	0.161
	Hardedge Stream	356.356	0.354	0.135
	Stream Elevation	356.439	0.437	0.129
	Non-suitable Suitable Stream	357.612	1.610	0.072
	NRFLow Hardedge Stream	357.775	1.773	0.066

Appendix P continued…

Table continued from previous page.

Owl	Model	AIC	ΔAIC	Weight
Lower Morine ♂	Hardedge Stream	322.362	0.000	0.286
	Non-suitable Suitable Hardedge Stream	322.430	0.068	0.277
	NRFLow Hardedge Stream	323.997	1.635	0.126
	Non-suitable Suitable Elevation Hardedge Stream	324.425	2.063	0.102
Miller Mountain ♀	NRFLow Elevation Hardedge	621.517	0.000	0.149
	NRFLow Hardedge	622.050	0.533	0.114
	NRFLow NRFMod Elevation Hardedge	622.839	1.322	0.077
	NRFLow Elevation Hardedge Stream	623.263	1.746	0.062
	Non-suitable Suitable Hardedge	623.275	1.758	0.062
	RFLow NRFLow Elevation Hardedge	623.378	1.861	0.059
	NRFLow NRFMod Hardedge	623.831	2.314	0.047
Miller Mountain ♂	Non-suitable Suitable Hardedge	592.070	0.000	0.345
	Non-suitable Suitable Hardedge Stream	592.815	0.745	0.238
	Non-suitable Suitable Elevation Hardedge	593.983	1.913	0.133
	Non-suitable Suitable Elevation Hardedge Stream	594.303	2.233	0.113
Oliver Springs ♂	NRFLow Road	478.890	0.000	0.410
	RFLow NRFLow Road	480.407	1.517	0.192
	NRFLow NRFMod Road	480.663	1.773	0.169
	RFLow RFMod NRFLow NRFMod Road	481.735	2.845	0.099
South Boundary ♂	Hardedge	450.969	0.000	0.091
	NRFLow Hardedge	451.083	0.114	0.086
	aspect	452.321	1.352	0.046
	Hardedge Stream	452.416	1.447	0.044
	NRFLow Elevation Hardedge	452.454	1.485	0.043
	NRFLow Hardedge Stream	452.471	1.502	0.043
	NRF	452.619	1.650	0.040
	NRFLow	452.702	1.733	0.038
	RFLow NRFLow Hardedge	452.835	1.866	0.036
	NRFLow NRFMod Hardedge	453.035	2.066	0.032

Appendix P continued…

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Owl	Model	AIC	ΔAIC	Weight
Upper Timber ♀	NRFLow	333.139	0.000	0.120
	NRFLow NRFMod	334.053	0.914	0.076
	NRFLow Hardedge	334.268	1.129	0.068
	NRFLow Road	334.639	1.500	0.057
	RFLow NRFLow	334.749	1.610	0.054
	NRFLow NRFMod Road	334.774	1.635	0.053
	NRFLow Elevation	335.039	1.900	0.046
	NRFLow Stream	335.137	1.998	0.044
	NRFLow NRFMod Hardedge	335.158	2.019	0.044
Upper Timber ♂	RFLow RFMod NRFLow NRFMod Elevation	417.302	0.000	0.117
	RFLow RFMod NRFLow NRFMod	417.591	0.289	0.102
	RFLow RFMod NRFLow NRFMod Stream	417.980	0.678	0.084
	RFLow RFMod NRFLow NRFMod Road	418.078	0.776	0.080
	RFLow RFMod NRFLow NRFMod High Elevation	418.851	1.549	0.054
	RFLow RFMod NRFLow NRFMod Stream Elevation	419.061	1.759	0.049
	RFLow RFMod NRFLow NRFMod Elevation Hardedge	419.289	1.987	0.043
	RFLow RFMod NRFLow NRFMod High	419.479	2.177	0.040
Yale Creek ♀	NRFLow Stream	420.266	0.000	0.101
	Stream	420.304	0.038	0.099
	NRFLow	420.723	0.457	0.080
	Stream Elevation	421.436	1.170	0.056
	Hardedge Stream	421.686	1.420	0.050
	NRFLow Hardedge Stream	421.709	1.443	0.049
	Low	421.939	1.673	0.044
	NRFLow Stream Elevation	422.134	1.868	0.040
	Non-suitable Suitable Stream	422.189	1.923	0.039
	RFLow NRFLow Stream	422.211	1.945	0.038
	NRFLow Elevation	422.445	2.179	0.034

Appendix Q. Relationships of parameters that frequently appear in the top model of breeding season habitat selection models of individual owls at the Timbered Rock and Quartz Fires, September, 2004 to August, 2006.

		Percent of	Relationship		
Group	Parameter	Models	Selected/Closer	Avoided/Further	Not Significant
Fire Owls	Distance * NRF - Low/Unburned[a]	9%	0	0	1
	NRF - Low/Unburned	45%	2	0	3
	NRF - Moderate	18%	0	0	2
	NRF - Low and Moderate	9%	1	0	0
	RF - Low/Unburned	9%	0	0	1
	RF - Moderate	9%	0	0	1
	RF - Low and Moderate	9%	1	0	0
	Non-Suitable	9%	0	0	1
	Suitable	9%	1	0	0
	Low Severity	18%	2	0	0
	High Severity	18%	0	0	2
	Salvage	9%	0	0	1
	Distance to Stream	36%	1	0	3
	Distance to Hard Edge	55%	3	1	2
	Used Lower Elevations	9%	0	0	1
	Distance to Road	9%	0	0	1
Outside Owls	Distance * NRF - Low/Unburned	10%	1	0	0
	NRF - Low/Unburned	40%	4	0	0
	RF - Low/Unburned	10%	1	0	0
	Aspect	20%	1	0	1
	Distance to Stream	30%	2	0	1
	Distance to Hard Edge	10%	0	0	1
	Distance to Road	10%	1	0	0
	Used Lower Elevations	20%	2	0	0

* 19 of 21 owls had a polynomial distance function included in the best model, the remaining two had a linear distance function

a - Interaction between distance from site center and NRF - Low/Unburned habitat, dexcribing a decrease in the probability of using NRF - Low/Unburned habitat as distance from site center increases.

Appendix R. Relationships of parameters that frequently appear in the top model of non-breeding season habitat selection models of individual owls at the Timbered Rock and Quartz Fires, September, 2004 to August, 2006.

			Relationship		
Group	Parameter	Percent of Models	Selected/Closer	Avoided/Further	Not Significant
Fire Owls	NRF - Low/Unburned	75%	7	0	2
	NRF - Moderate	50%	2	0	4
	RF - Low/Unburned	25%	0	0	3
	RF - Moderate	25%	1	0	2
	Non-Suitable	17%	1	0	1
	Suitable	17%	2	0	0
	High Severity	8%	1	0	0
	Distance to Stream	42%	4	0	1
	Distance to Hard Edge	50%	3	0	3
	Used Lower Elevations	50%	3	0	3
Outside Owls	NRF - Low/Unburned	56%	4	0	1
	RF - Low/Unburned	11%	1	0	0
	Aspect	11%	0	0	1
	Distance to Stream	44%	2	1	1
	Distance to Hard Edge	22%	1	0	1
	Distance to Road	33%	2	1	0
	Used Lower Elevations	11%	0	1	0

Appendix S. Comparison of the distribution of habitats near riparian areas to the distribution of habitats in the entire Timbered Rock Study Area.

Post-fire habitat selection results indicated that northern spotted owls (*Strix occidentalis caurina*) selected areas that were closer to perennial streams and lower in elevation than at random. To determine if quality spotted owl habitat was unequally distributed in regards to riparian areas I compared the distribution of habitats within the entire study area to habitats within a 50 m, 100 m, 200 m and 400 m buffer of perennial streams (Figure 1). Visual comparisons indicate that there was little difference in distributions of habitats closer to streams than in the entire study area.

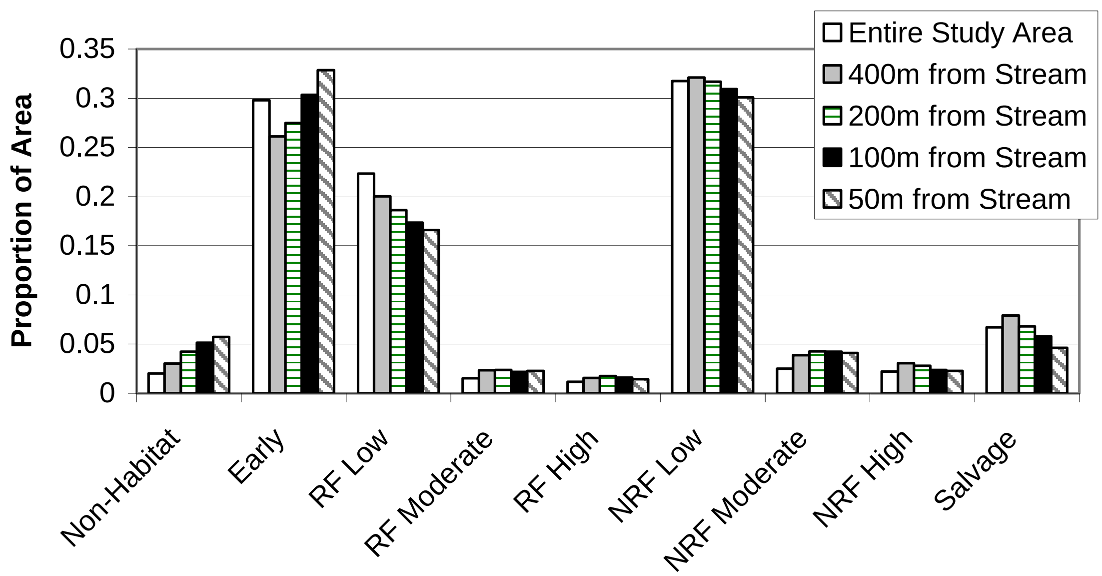

Figure 1. Visual representation of the distribution of habitats within the Timbered Rock Study Area in comparison to the distribution of habitats within 4 buffer distances of riparian areas.